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THE OXIDATION-REDUCTION POTENTIALS OF ALABAMA SOILS AS AFFECTED BY SOIL TYPE, SOIL MOISTURE, CULTIVATION, AND VEGETATION[1]

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OXIDATION-REDUCTION potentials of soils have been used by a number of workers during the past five years for interpreting certain soil phenomena associated with plant growth and bacterial action. Bradfield, Batjer, and Oskamp (1)[3] published data in 1934 indicating that a relationship exists between the productiveness of apple trees and the redox potential of the soils in New York State. Sturgis (11) found that reduction was intense in waterlogged rice fields provided active organic matter was present, but the Eh values obtained could not be used to interpret the ability of submerged soil to produce rice. According to Breazeale and McGeorge (2), reduction (especially denitrification) begins when the puddling point has been reached in soils. Results obtained by Burrows and Cordon (3) revealed that different forms of organic matter caused different types of bacterial action and affected the development of different potentials. Remezov (9), working with podzols poor in humus, observed no changes in Eh on standing and concluded that changes in Eh are affected by weather, supply of organic matter, and biological action. Heintze (4) obtained reduction in soils in one to two days time by waterlogging them in the presence of easily decomposable organic matter. Data are presented by Kononova (6) to show that for certain soils the flood system of irrigation caused a fall in Eh and increased denitrification while furrow irrigation caused no such reactions. Smolik (10) found that drainage by means of tile caused a rise in Eh of 90 to 250 millivolts for certain podzols. Herzner (5), in studying the Eh of subsoils, found them to be more or less constant, due, he believed, to the absence of bacteria.

Remezov (8), while investigating the dyanamics of oxidation-reduction potentials, found that as podzols became more swampy the Eh fell. He also found that Eh decreased with depth, that sandy soils

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[3]Figures in parenthesis refer to "Literature Cited", p. 588.

varied more in Eh during the season than did clays, and that climatic factors caused greater differences in Eh than did cultural practices or vegetation.

In view of the results obtained by some of the above investigators, a project was begun at the Alabama Agricultural Experiment Station in 1936 for the purpose of determining the relation of redox potentials of soils to soil characteristics, fertility, weathering processes, decomposition of organic matter, and plant ecology. The present paper deals with the factors affecting soil Eh and with the magnitude of seasonal fluctuations of the Eh of Alabama soils under different cultural practices.

SELECTION OF SOIL AREAS AND METHOD OF SAMPLING

Since cultural practices might affect the Eh of soils, wherever possible two adjacent areas were selected on a given soil type—one being cultivated and the other being woodland or grassland. In most instances the two areas selected were not over 100 feet apart. These areas were carefully located on 24 different soil types scattered over the northern two-thirds of Alabama, several of which were located in each of the different soil provinces. The soil types selected are given in Table 1 and, as will be noted, they include most of the common agricultural soils of the state.

TABLE 1.—*The arrangement of noncultivated soil types according to the average annual Eh value of the 0- to 8-inch depth.*

Soil	Eh at pH 6.0	Soil	Eh at pH 6.0	Soil	Eh at pH 6.0
Durham fine sandy loam	496	Cecil sandy loam	521	Waynesboro clay loam	538
Wehadkee clay	501	Hanceville fine sandy loam	523	Congaree clay loam	539
Norfolk sandy loam	511	Leaf fine sandy loam	528	Eutaw clay	540
Decatur clay loam	512	Amite clay loam	531	Atkins clay	541
Colbert clay	514	Kalmia fine sandy loam	535	Catalpa clay	546
Houston clay	515	Oktibbeha clay	536	Davidson clay loam	549
Huntington clay loam	519	Holly clay	536	Vaiden clay loam	550
Pope clay	520	Susquehanna sandy loam	537	Vaiden clay loam (buckshot)	552

In order to obtain representative samples of these soils every 2 weeks throughout the year, five holes were bored at each location at each sampling date. Care was taken not to contaminate the soils from the 0- to 8-inch, the 8- to 16- inch, and the 16- to 24-inch depths with each other. Each composite of five borings was quickly and thoroughly mixed and a portion of it was immediately placed in a 60-cc bottle containing 30 cc of water saturated with nitrogen and cooled to about 35° F. Enough soil was added to push the water just into the neck of the bottle, as this insured a uniform size of sample and at the same time excluded all of the air. The bottle was then corked with a paraffined cork and replaced in a cooler to prevent reduction (12). Another portion of the soil was placed in an airtight container and its moisture content determined later.

METHODS OF ANALYSES

The analyses for redox potential and pH were made simultaneously within 72 to 96 hours after sampling according to the methods described in a previous paper (12). In addition to Eh and pH, the moisture content of the soil at sampling time was determined.

FACTORS AFFECTING SOIL EH

SOIL TYPE

Since Eh is dependent on the kinds of ions in solution, their states of oxidation, and their relative concentrations, it appeared likely that different soil types under similar cultural practices might have different Eh values, and this proved to be the case. In order to avoid man-induced complications existing in cultivated soils, it is best to consider only virgin areas when attempting to study any relation that may exist between soil Eh and soil type. The virgin soils studied in Alabama have been arranged according to their average annual Eh values as shown in Tables 1, 2, and 3. When the results are examined, differences are found in Eh values of soils which are difficult to explain. For example, Atkins clay, Catalpa clay, and Holly clay, which are more or less swampy soils known to be in a waterlogged state for long periods of time, were found to be considerably higher in Eh than several soils known to be well-oxidized, such as Decatur clay loam and Cecil sandy loam.

TABLE 2.—*The arrangement of noncultivated soil types according to the average annual Eh of the 8- to 16-inch depth.*

Soil	Eh at ph 6.0	Soil	Eh at pH 6.0	Soil	Eh at pH 6.0
Wehadkee clay	297	Amite clay loam	528	Holly clay	540
Houston clay	505	Oktibbeha clay	530	Leaf fine sandy loam	541
Colbert clay	510	Waynesboro clay loam	532	Eutaw clay	542
Decatur clay loam	513	Norfolk sandy loam	532	Catalpa clay	549
Huntington clay loam	517	Susquehanna sandy loam	533	Davidson clay loam	551
Durham fine sandy loam	519	Hanceville fine sandy loam	533	Congaree clay loam	552
Cecil sandy loam	521	Vaiden clay loam (buckshot)	535	Atkins clay	552
Pope clay	521	Vaiden clay loam	538	Kalmia fine sandy loam	553

Because of these results it is considered inadvisable to compare one soil type with another as regards Eh and to interpret from that comparison a difference in the states of oxidation. Peech and Boynton (7) have shown that poorly drained soils often contain MnO_2 concretions. It is possible that such a condition existed in Atkins clay, Catalpa clay, and Holly clay and that stirring of those soils during analysis allowed the MnO_2 to oxidize certain compounds existing in those soils in a reduced state. To the author, however, it seemed more reasonable to believe that the Eh of those particular soils was more dependent on

the kinds and ratios of materials in solution than upon the states of oxidation of those materials. The above statement, however, does not mean that reduction of the compounds existing in a given soil would not cause a drop in potential.

TABLE 3.—*The arrangement of noncultivated soil types according to the average annual Eh of the 16- to 24-inch depth.*

Soil	Eh at ph 6.0	Soil	Eh at pH 6.0	Soil	Eh at pH 6.0
Wehadkee clay	315	Susquehanna sandy loam	520	Leaf fine sandy loam	534
Cecil sandy loam	479	Pope clay	520	Waynesboro clay loam	536
Colbert clay	483	Vaiden clay loam	523	Catalpa clay	539
Houston clay	503	Norfolk sandy loam	524	Holly clay	541
Amite clay loam	504	Hanceville fine sandy loam	525	Atkins clay	545
Durham fine sandy loam	509	Decatur clay loam	525	Kalmia fine sandy loam	550
Huntington clay loam	515	Vaiden clay loam (buckshot)	527	Davidson clay loam	552
Oktibbeha clay	519	Eutaw clay	534	Congaree clay loam	555

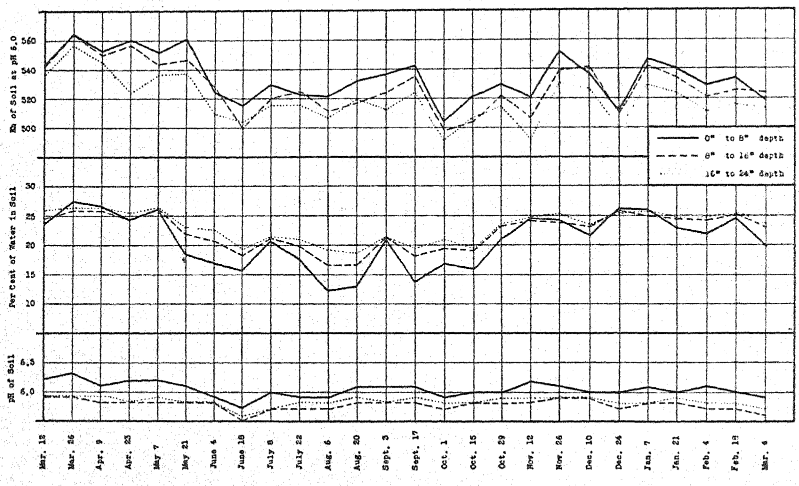

FIG. 1.—Seasonal fluctuations in Eh, pH, and soil moisture at three depths for the average of 40 arable soils of Alabama.

CULTIVATION VS. CONTINUOUS VEGETATIVE COVER

There is ample evidence to show that the decomposition of organic matter under waterlogged conditions usually results in a marked lowering of the Eh even though different kinds of organic matter produce different by-products during decomposition and thus affect the potential differently (3). Since the cultivation of soils causes a depletion of organic matter, it is reasonable to expect that cultivated soils will have higher potentials than corresponding soils under con-

tinuous vegetation (grass and trees). A study of the data in Table 4 shows that there is a difference in the Eh of the surface of cultivated and noncultivated soils in many cases, but that no consistent differ-

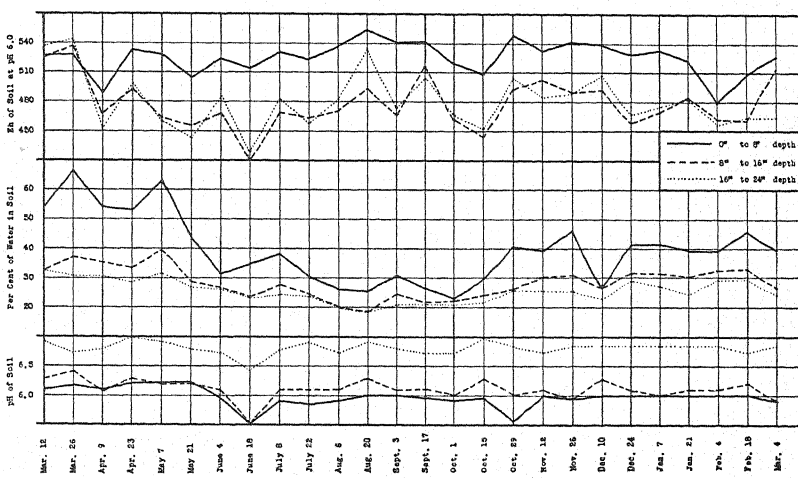

FIG. 2.—Seasonal fluctuations in Eh, pH, and soil moisture at three depths for the average of four swampy soils of Alabama: Wehadkee clay, Holly clay, Pope clay, and Atkins clay.

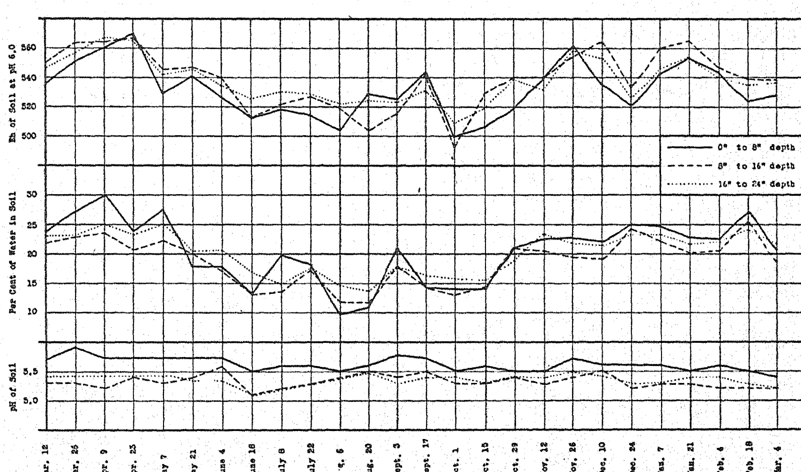

FIG 3.—Seasonal fluctuations in Eh, pH, and soil moisture for Congaree clay loam, Huntington clay loam, Waynesboro clay loam, Leaf fine sandy loam, and Kalmia fine sandy loam (woodland soils).

ence exists in the subsoils. The greatest differences were found to occur in the alkaline Black Belt soils where grassland showed an average of 44 millivolts lower than cultivated land in the surface 0- to 8-inches

TABLE 4.—*The average annual Eh of cultivated soils as compared with woodland or grassland soils.*

Soil type	Eh of soils in millivolts at pH 6.0					
	0–8 in. depth		8–16 in. depth		16–24 in. depth	
	Cultivated	Woodland and grassland	Cultivated	Woodland and grassland	Cultivated	Woodland and grassland
Piedmont						
Cecil sandy loam	519	521	518	521	483	479
Davidson clay loam	548	549	553	551	547	552
Congaree clay loam	555	539	571	552	571	555
Durham fine sandy loam	542	496	521	519	491	509
Average	541	526	541	536	523	524
Limestone Valley						
Decatur clay loam	543	512	536	513	525	525
Huntington clay loam	543	519	544	517	537	515
Colbert clay	539	514	527	510	501	483
Average	542	515	536	513	521	508
Appalachian						
Hanceville fine sandy loam	525	523	533	533	529	525
Waynesboro clay loam	530	538	540	532	539	536
Average	528	531	537	533	534	531
Acid Black Belt						
Vaiden clay loam (buckshot)	518	552	509	535	519	527
Eutaw clay	532	540	520	542	513	534
Vaiden clay loam	576	550	552	538	542	523
Oktibbeha clay	546	536	526	530	520	519
Average	543	545	527	536	524	526
Alkaline Black Belt						
Catalpa clay	586	546	584	549	573	539
Houston clay	564	515	530	505	529	503
Average	575	531	557	527	551	521
Coastal Plain						
Leaf fine sandy loam	549	528	546	541	529	534
Kalmia fine sandy loam	497	535	506	553	516	550
Amite clay loam	538	531	522	528	506	504
Susquehanna sandy loam	525	537	498	533	494	520
Norfolk sandy loam	543	511	549	532	541	524
Average	530	528	524	537	517	526
Average for all soils	541	530	534	532	525	523

and about 30 millivolts lower in the 8- to 16- and 16- to 24-inch depths. These differences, however, appear to be of insufficient magnitude to be considered factors in affecting plant growth from the standpoint of potential alone.

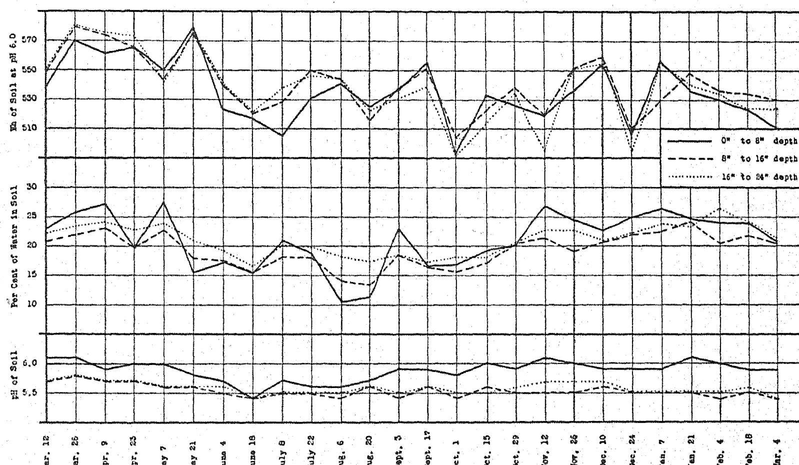

FIG. 4.—Seasonal fluctuations in Eh, pH, and soil moisture for Congaree clay loam, Huntington clay loam, Waynesboro clay loam, Leaf fine sandy loam, and Kalmia fine sandy loam (cultivated soils).

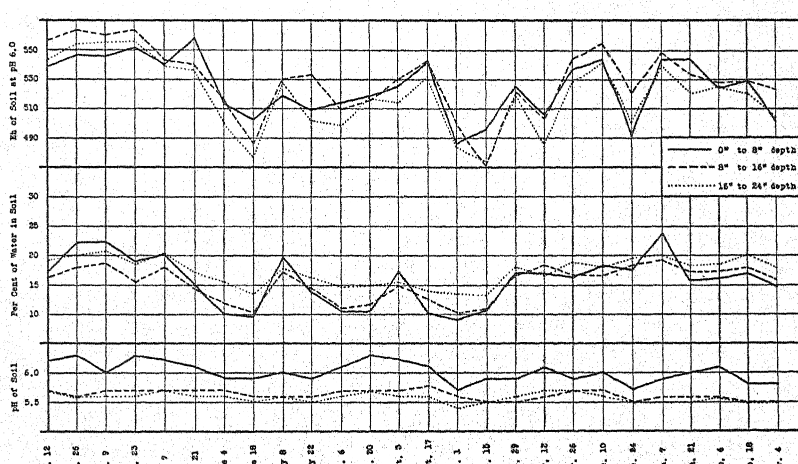

FIG. 5.—Seasonal fluctuations in Eh, pH, and soil moisture for Cecil sandy loam, Davidson clay loam, Decatur clay loam, Hanceville fine sandy loam, Amite clay loam, and Norfolk sandy loam (woodland soils).

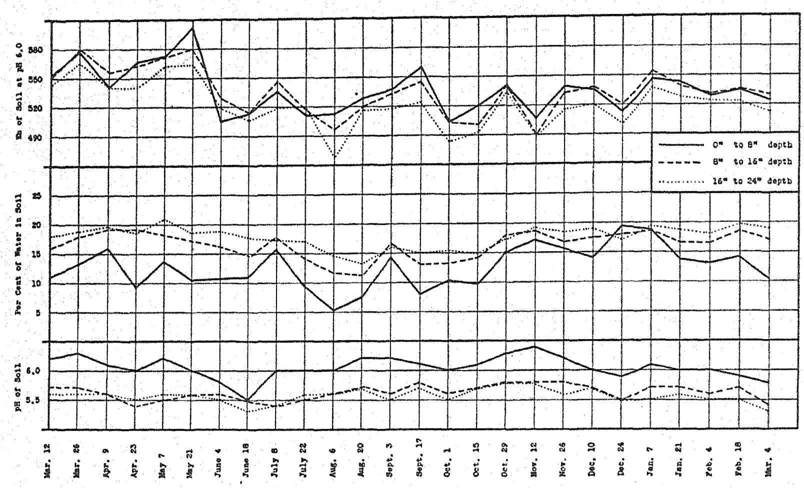

FIG. 6.—Seasonal fluctuations in Eh, pH, and soil moisture for Cecil sandy loam, Davidson clay loam, Decatur clay loam, Hanceville fine sandy loam, Amite clay loam, and Norfolk sandy loam (cultivated soils).

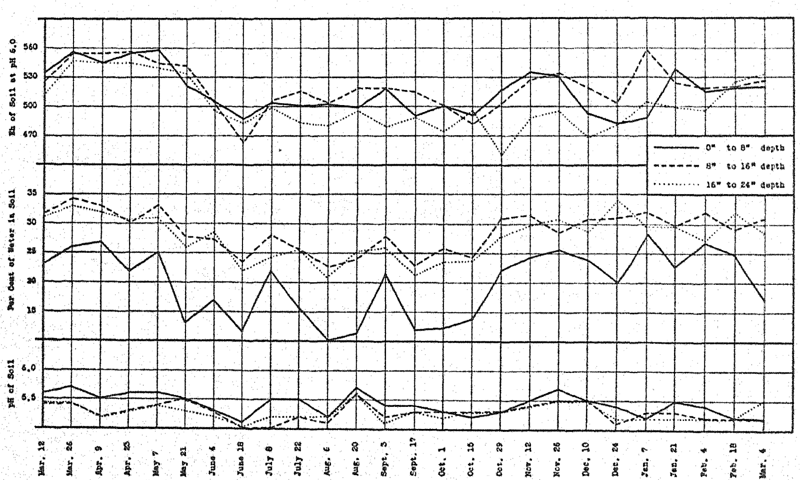

FIG. 7.—Seasonal fluctuations in Eh, pH, and soil moisture for Durham fine sandy loam, Colbert clay, and Susquehanna sandy loam (woodland soils).

SOIL MOISTURE

Previous to this study, it was generally believed that an increase in soil moisture would cause a lowering of soil Eh as a result of increased bacterial action. Results (Fig. 1) obtained at the Alabama Experiment Station, however, reveal that, while there is a definite relation between the amount of moisture in the soil and the resultant Eh, the relationship is the reverse of what might be expected. As the soil

moisture increases the Eh increases, and *vice versa*. A possible explanation of this may be as follows: The rain contains a good supply of oxygen and as it passes into the soil it oxidizes existing reduced compounds and causes a rise in the Eh of the soil. Later, the bacteria get into full action and deplete the soil of oxygen and it remains so until bacterial action subsides due to a lack of moisture or organic matter. Such a cycle in the soil could easily account for the results given in

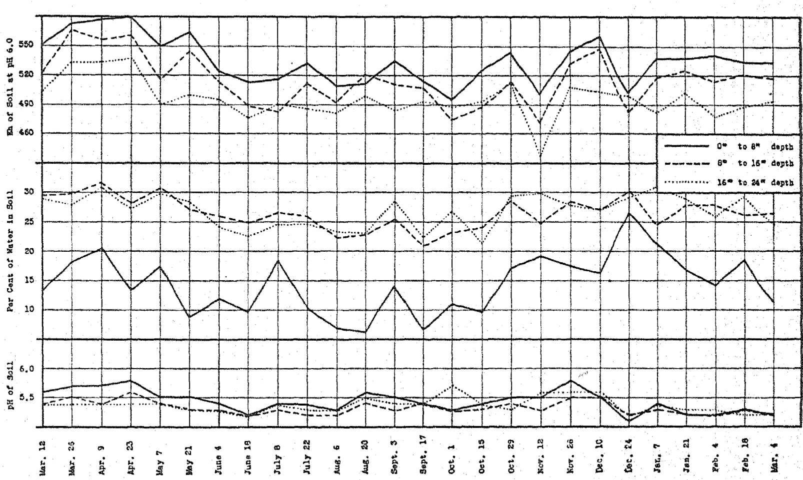

FIG. 8—Seasonal fluctuations in Eh, pH, and soil moisture for Durham fine sandy loam, Colbert clay, and Susquehanna sandy loam (cultivated soils).

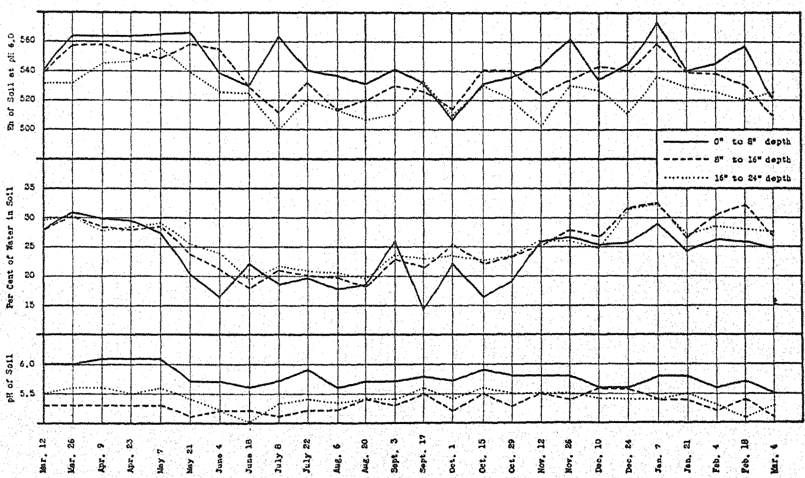

FIG. 9—Seasonal fluctuations in Eh, pH, and soil moisture for Vaiden clay loam (buckshot), Vaiden clay loam, Eutaw clay, and Oktibbeha clay (woodland soils).

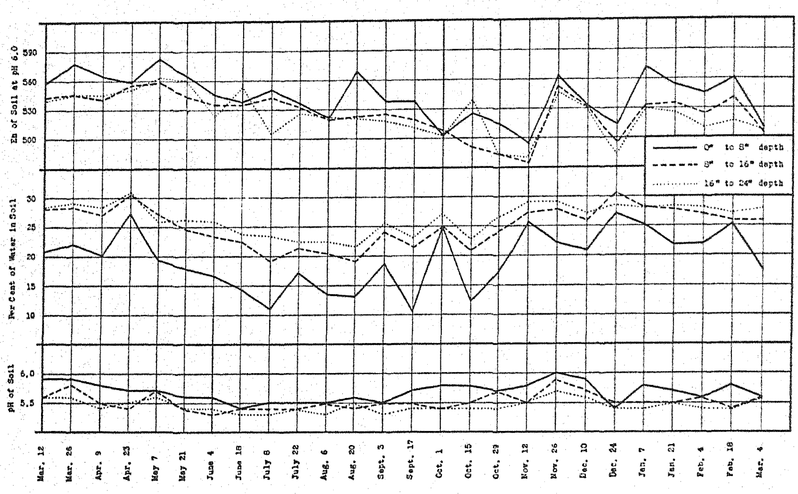

FIG. 10.—Seasonal fluctuations in Eh, pH, and soil moisture for Vaiden clay loam (buckshot), Vaiden clay loam, Eutaw clay, and Oktibbeha clay (cultivated soils).

Figs. 1 to 12, inclusive. The above theory is further supported by the fact that the Eh of a stagnant mudhole proved to be lower before a rain than after.

A study of Figs. 1 to 12, inclusive, shows that during the wet months (late fall, winter, and spring) the potential is the highest, while during the drier summer months the potential is lower. The above trend did not hold consistently in the case of swamp soils which

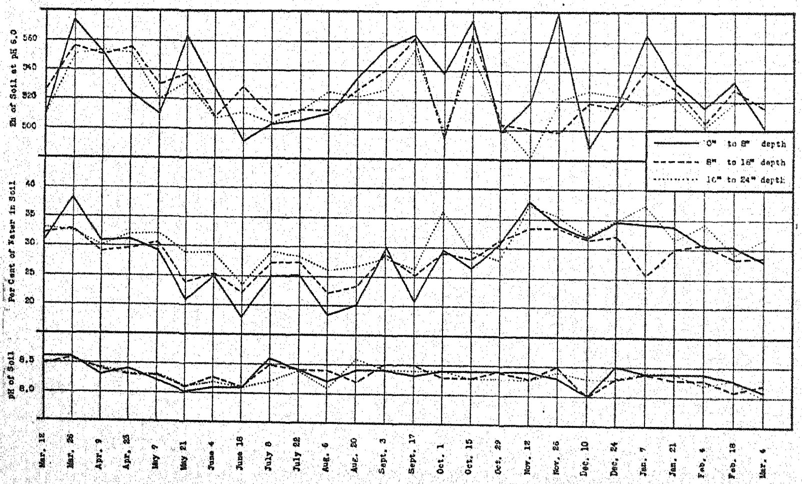

FIG. 11.—Seasonal fluctuations in Eh, pH, and soil moisture for Catalpa clay and Houston clay (woodland soils).

remained in a waterlogged state the greater part of the year (Fig. 2). The peculiar behavior of these swamp soils depends on a number of factors, such as the amount of material carried into them by flood water, the degree to which they dry out during certain seasons, the amount of food available to bacteria in the stagnant water, and the temperature of the water.

Even though seasonal fluctuations in Eh did occur for the arable soils, the fluctuations were of such small magnitudes (around 60 millivolts as a maximum as measured by the author's method) that it hardly seems possible that they could affect plant growth to any degree.

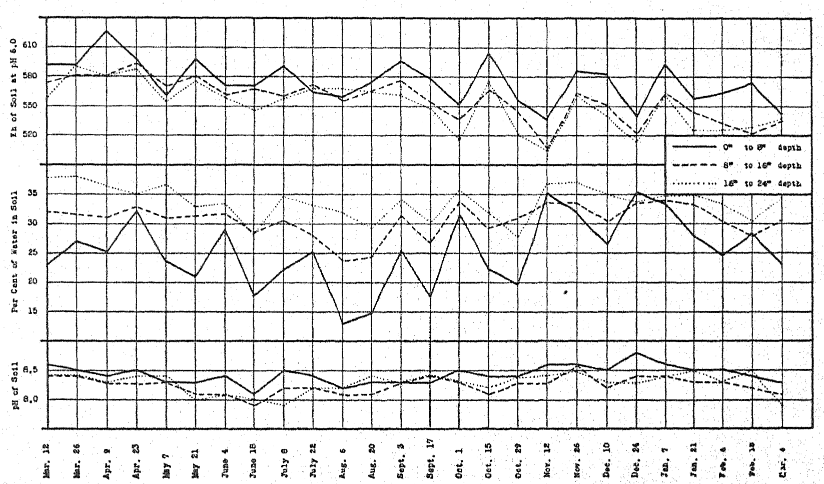

FIG. 12.—Seasonal fluctuations in Eh, pH, and soil moisture for Catalpa clay and Houston clay (cultivated soils).

DISCUSSION

The Eh of a soil is the intensity factor in oxidation and reduction just as pH is the intensity factor in soil acidity—the pH is dependent on the hydrogen-ion concentration, whereas the Eh is dependent on the relative concentrations and states of oxidation of all ions present and thus must be calculated to a common pH value for comparative purposes. Different ions in the same state of oxidation have different Eh values and identical ions in different states of oxidation have different Eh values. Thus it is believed that it is possible for some ions existing in an oxidized state in soils to have lower Eh values than other ions existing in soils in a reduced state. Therefore, when the Eh of any given soil is obtained it is doubtful whether or not its state of oxidation or reduction is known since the potential depends not only on the ratio of oxidized to reduced phases of the ions present but also on the kinds and relative amounts of ions present. Also, if a particular soil changes in Eh during the season, one cannot definitely say there is a change in the state of oxidation because the factor or factors

causing the change in Eh may have brought into solution or thrown out of solution ions of different chemical composition and different Eh values without altering the state of oxidation of the soil as a whole.

Considering the points set forth above, it is believed quite possible that the changes in Eh occurring in arable Alabama soils are of little consequence as regards plant growth. A study dealing with this phase of the problem is in progress and the results will be reported at a later date.

SUMMARY

This study was undertaken for the purpose of determining some of the factors affecting soil Eh and to determine the magnitude of the fluctuations in Eh for different Alabama soils under different cultural practices. The results obtained are as follows:

1. Cultivated soils generally have a slightly higher Eh (about 10 millivolts) in the 0- to 8-inch depth than do woodland and grassland soils, but this difference is not carried into the subsoil as a rule.

2. Differences in Eh due to soil types do exist, but the differences are small for arable soils, seldom being over 50 millivolts. Data obtained indicate that these differences are often due to variations in soil material rather than to differences in states of oxidation—swampy soils frequently have higher Eh values than do well-aerated upland soils.

3. Increases in moisture in arable soils caused increases in Eh, and *vice versa*. This condition, it is believed, was brought about by oxygen being carried into the soil by rainwater which caused reduced compounds to become oxidized, and later the increased moisture caused increased bacterial action which resulted in a consumption of the oxygen and a lowering of the potential.

4. The seasonal variations in Eh for any arable soil in Alabama seldom exceed 60 millivolts.

5. It appears that Eh determinations do not reveal whether or not an arable soil is in an oxidized or reduced state since the Eh is dependent not only on the ratio of the oxidized to the reduced phases of the ions present but also on the kinds and relative amounts of the ions present.

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THE LATERAL DISTRIBUTION OF POTASSIUM IN AN ORCHARD SOIL[1]

J. H. Gourley and Irvin W. Wander[2]

A PREVIOUS report (1)[3] has shown that potassium moves downward slowly in Wooster silt loam soil. Since fruit trees root deeply (from 5 to 6 feet) in this soil, the problem arose as to what method could be employed to supply tree roots with available potassium in case it became necessary or desirable to apply this element. Plainly, a surface application in either a sod or tilled orchard on this soil type would reach the mass of absorbing roots rather slowly, if at all.

In order to test experimentally a method of "deep" application, a set of holes was bored beneath certain trees and a potash fertilizer was introduced in orchard J, plat 7. The orchard used and the procedure were as follows:

An orchard of apple trees was planted in 1922, consisting of Baldwin and Stayman Winesap varieties. Cultivation with cover crops was followed as a cultural system for a few years and then the land was seeded to a nonlegume cover (mostly timothy and blue-grass). Incidentally, this was for the purpose of reducing the naturally occurring nitrate supply and thus bring about an earlier response to nitrogen-carrying fertilizers. One row of 19 trees has been treated with muriate or sulfate of potash together with nitrate of soda since 1928. But, as shown previously, the downward translocation of the potassium has been slow.

In 1935 a soil "plugging" test was started and 16 holes were bored to a depth of 18 inches beneath 10 of the 19 trees in the row. A geometric design was used and mapped so that any hole could be readily located at any time in the future. Thus, eight holes were bored with a king soil tube in a 12-foot circle from the base of the tree and another eight holes were bored in a 9-foot circle alternating with the holes in the 12-foot circle. All the holes were beneath the branches of the trees. The following year 16 holes were again made just outside the periphery of the branches for the fertilizer treatment, but only those treated in 1935 are considered here.

Sixty grams of a potash salt were mixed with approximately two-thirds of the soil removed and this mixture was inserted into the lower 12 inches of each hole (6 inches to 18 inches).

Two or three questions arise as to the ultimate disposition of the exchangeable potassium, whether or not it distributes downward only, laterally also, or is largely immobile. Furthermore, what is the effect of this concentration of salt upon fibrous roots already in close proximity to the holes, do new ones develop in the adjacent soil, and is there an uptake of K into the tree? The first of these questions is here principally considered.

In order to determine whether there has been any movement of the K in a period of three years, samples were taken for quick tests (2) between July 10 and August 16, 1938. A pit was dug 3 feet wide, 4 feet long, and 3 feet deep along the

[1]Contribution from the Department of Horticulture, Ohio Agricultural Experiment Station, Wooster, Ohio. Received for publication February 25, 1939.
[2]Head of Department and Assistant Horticulturist, respectively.
[3]Figures in parenthesis refer to "Literature Cited", p. 597.

side of the cores into which had been placed the potash and soil mixtures (trees 6, Fig. 1).

Samples were taken 1 inch wide, 1 inch thick, and 6 inches long on either side of the core at 1-inch intervals laterally to a distance of 10 inches. In most cases

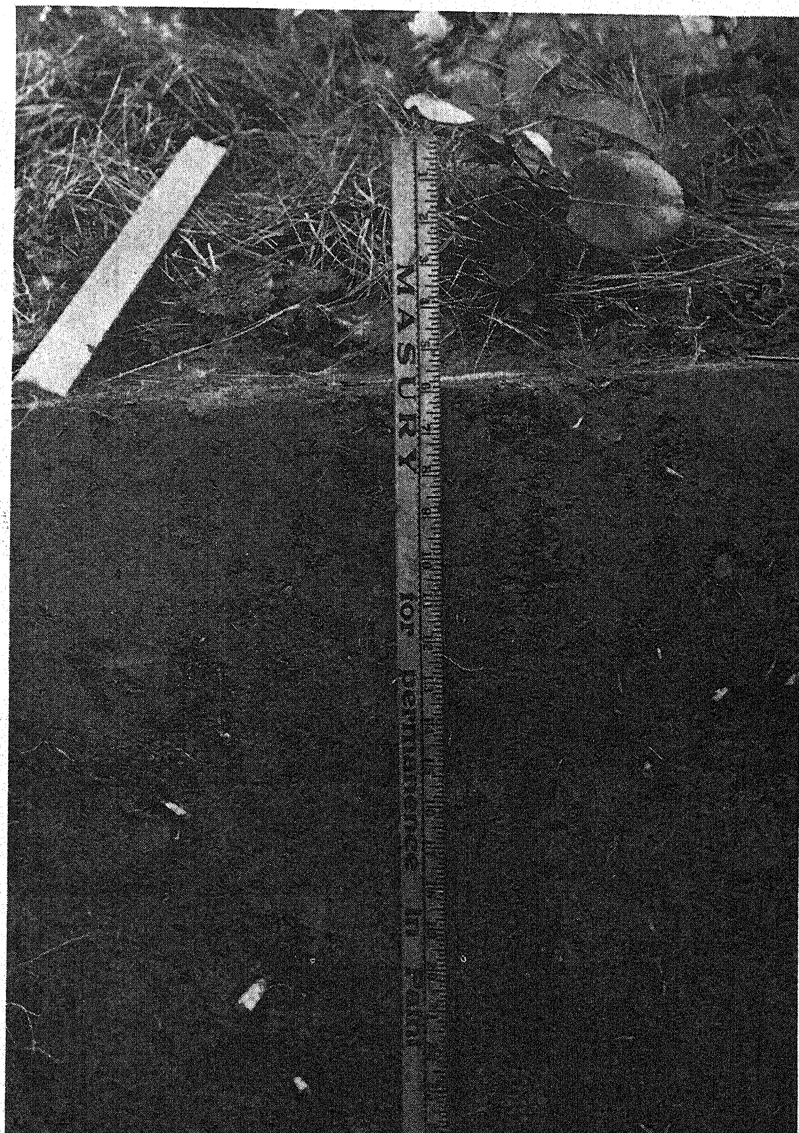

FIG. 1.—To the right of yardstick is shown the core of soil containing the potash salt.

the depth of the samples was limited to 24 inches because of shale encountered. Thus, in all cases except one (tree 19, Fig. 6), a total of 84 samples were taken per core. In this latter case it was necessary to go further out from the side of the core in order to determine the periphery of the zone of very high available potassium.[4]

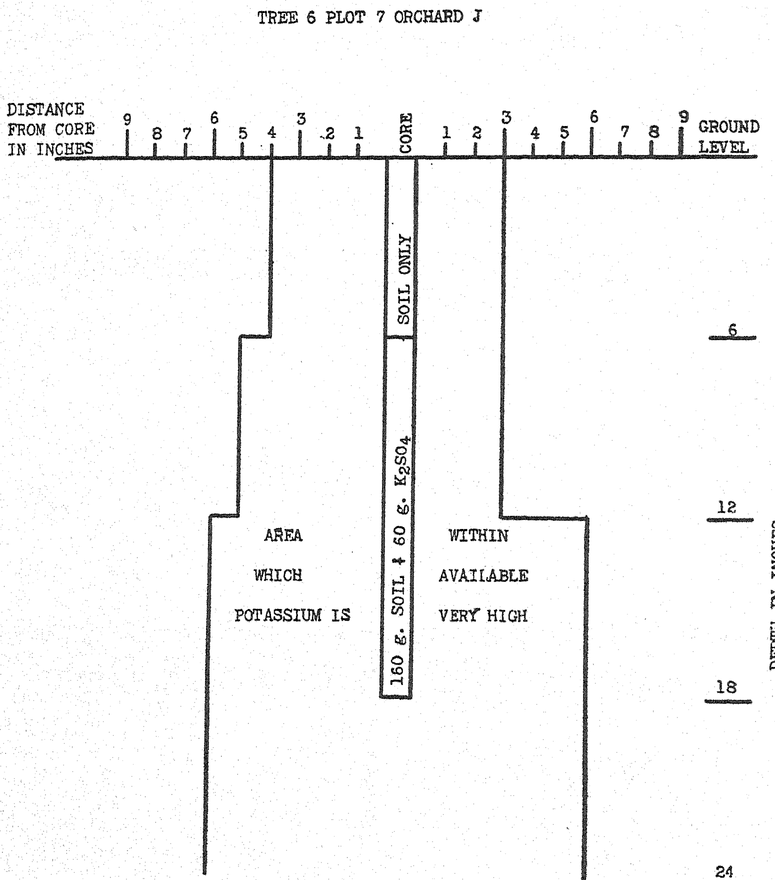

FIG. 2.—Diagram showing the lateral distribution of exchangeable potassium from core shown in center of figure.

RESULTS

The first tree studied (tree 6) showed that not only had there been lateral movement of the K but that the soil water presumably had carried it upward to the surface and also laterally to a distance of

[4]The quick test used was developed at Purdue University and is known as the "Thornton test." In general, the test for potassium consists of thoroughly mixing 1 teaspoon of air-dried, screened soil with a solution of sodium cobaltinitrite in acetic acid. The amount of potassium is then estimated by adding isopropyl alcohol to an aliquot of the filtrate and judging the turbidity formed by the precipitate. This method was found to give reproducable results when used on these particular soil samples.

3 inches on one side to 4 inches on the other so that it tested "very high" in that 6-inch surface zone where no K had been inserted (Fig. 2). In the 6- to 12-inch zone the soil tested very high to 3 inches on one side and 5 inches on the other, from 12 to 18 inches the distribution had widened in a radius of 6 inches. It had also penetrated to a depth of at least 24 inches and 6 inches on either side of the core or axis. In other words, these boundaries represent the limits to which the bulk of available K has penetrated since the transition from "very high" to "low" or "very low" does not extend more than 2 or 3 inches beyond. Thus, the general contour of the movement was roughly in the shape of a flask or bottle.

Cores selected at random under trees 10, 11, 14, and 19 were likewise studied. The picture varies somewhat from tree to tree, probably due to variations in soil texture and slope of strata, but in the main confirms the findings of the first one, namely, that there is a decided lateral movement of this element in the soil.

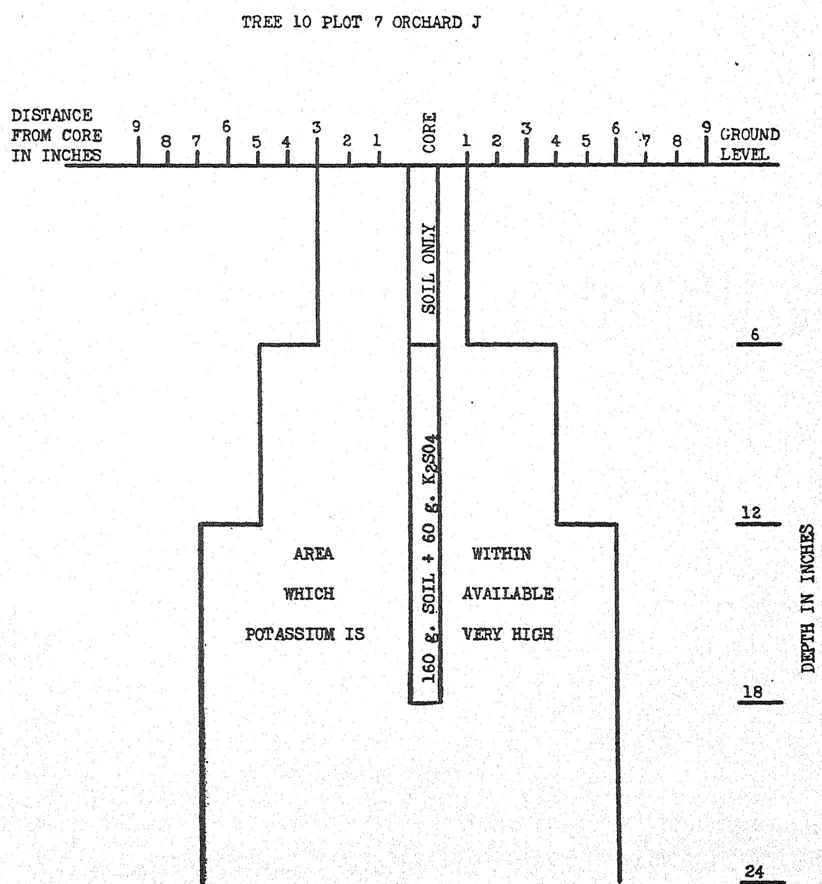

FIG. 3.—Diagram of tree 10 showing distribution of potassium.

Tree 10 shows a pattern quite similar to that found under tree 6. In both cases sulfate of potash was used (Fig. 3).

Tree 11, where the muriate form of the salt was used, shows a reversal in pattern in that the widest distribution is at the upper 6 inches where the core was filled with soil only. At the base the radius from the core is 5 and 6 inches, respectively (Fig. 4). That this difference is due to the form of salt used is not suggested but is worthy of note.

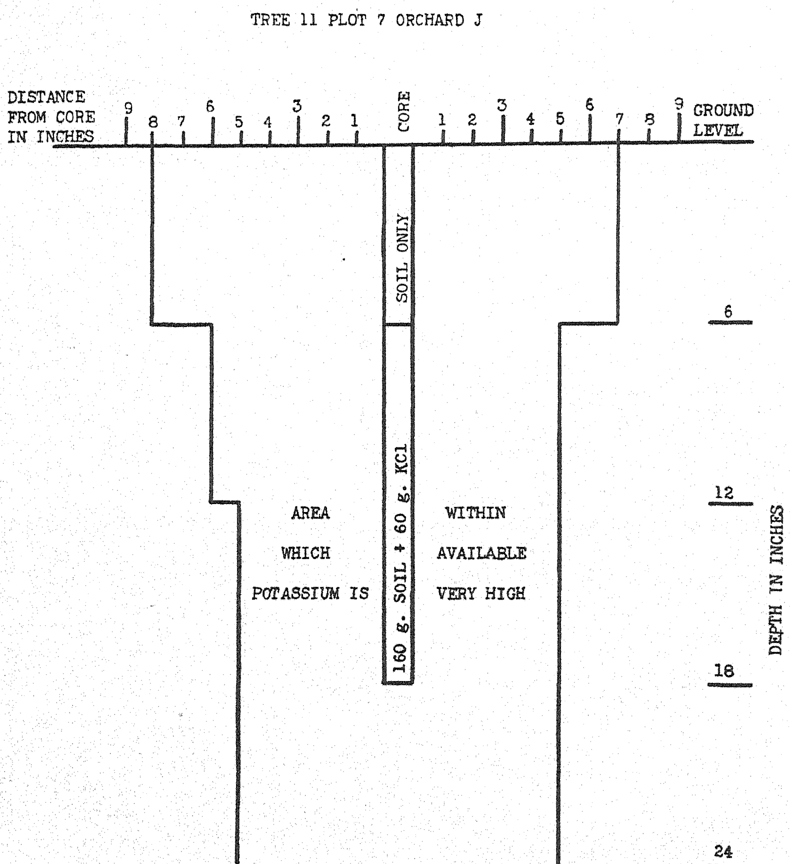

FIG. 4.—Diagram of tree 11 showing distribution of potassium. Note the difference in shape of the outline compared to the preceding figures.

The samples taken beneath tree 14 show a more irregular outline with a wider distribution on one side than the other below a level of 12 inches (Fig. 5).

The core selected beneath tree 19 showed a still greater variation from the others. The movement for the entire depth is nearly unilateral but involves a wide area, being 16 inches in the upper level (Fig. 6).

While no quantitative determinations were made, it was observed throughout these excavations that live, fibrous roots were present within the zone of "very high" potassium. This would mean that a tree deficient in K should obtain ample supplies from the soil, if some such technic as that here described were used.

Volk (3) and Volk (4) found that the alternate wetting and drying of a mixture of a soluble potassium salt and certain soils at 70° C

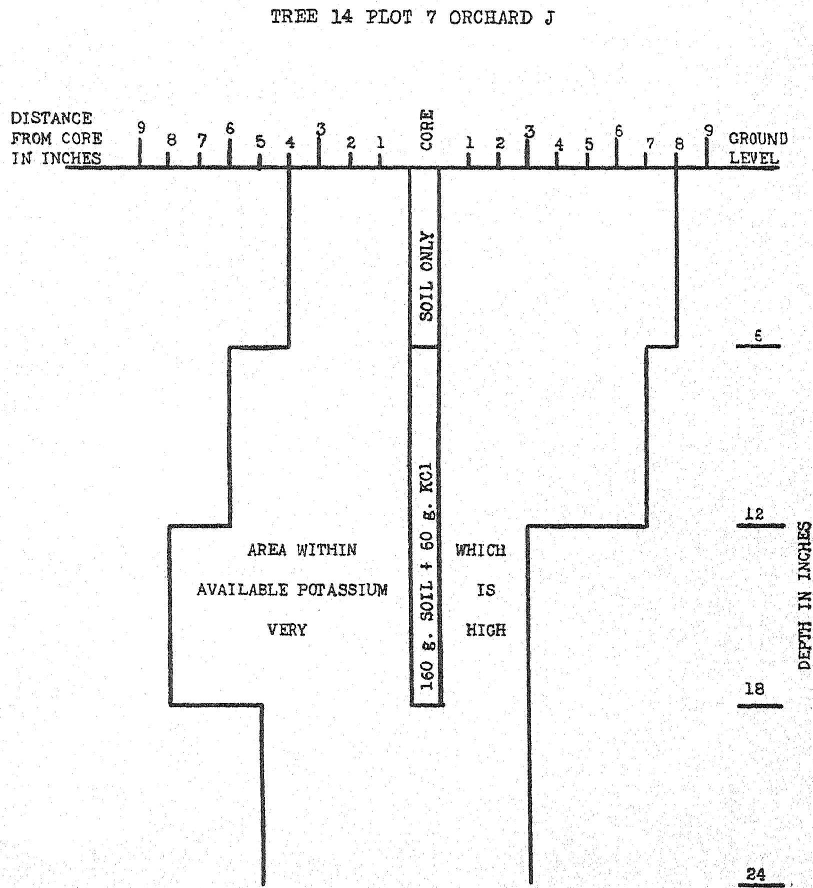

FIG. 5.—Diagram of tree 14 showing distribution of potassium.

caused a large amount of the potassium to be fixed in a difficultly available form. Thus, potash applied on the surface or just slightly beneath the surface of a soil will fail to move downward to any appreciable extent since this zone would be subject to alternate wetting and drying. But, they also found that when soluble potassium is in contact with soil under continuous moist conditions, such as would be found at the lower soil depths, fixation is very slow.

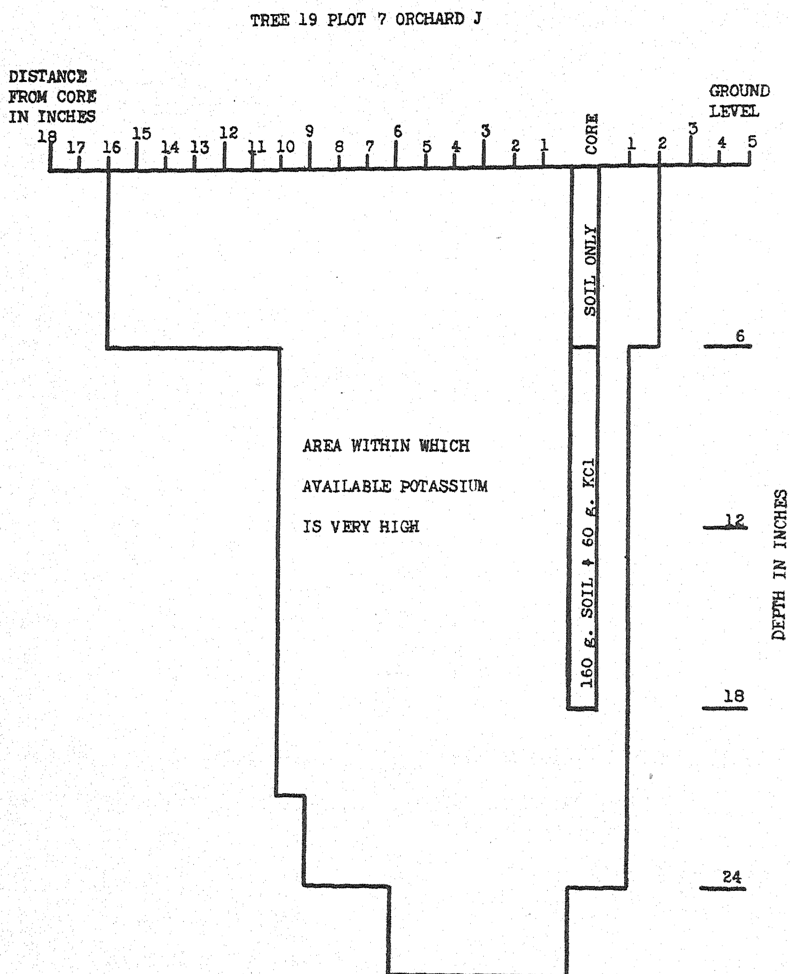

FIG. 6.—Diagram of tree 19 showing distribution of potassium. Note the predominate distribution to the left side.

Truog and Jones (5) explain the fixation of potassium in their conclusions by stating that, "when the exchange material is saturated with potassium and the material is then dried, which is supposed to bring the layers or plates of the crystal lattice together, the presence of the potassium offers such strong attraction as to prevent reexpansion of the crystal lattice and thus reentrance of water and opening up of the crystal lattice, causing the potassium to become trapped in non-exchangeable form."

Furthermore, they state that the, "introduction of organic matter, which supplies organic base exchange material, should also be helpful, since entrance of potassium in the organic exchange material renders

the potassium safe from fixation in non-exchangeable form for the time being."

These suggestions and conclusions fit closely the observations which have been reported in this paper as well as previously (1), showing the large amount of exchangeable potassium found under mulched apple trees with straw and similar organic materials.

DISCUSSION AND SUMMARY

This investigation of potassium movement in the soil is of interest to horticulturists from several standpoints, particularly to those who have to deal with a deficiency of this element in orchards.

The first objective was that of determining whether there would be a lateral movement of sufficient extent to make potassium available to a mass of tree roots without injury to the new ones which develop in such a zone.

It is interesting to note that these areas represent from 1.4 to 2.2 cubic feet of soil per core in which the available K has become very high within a period of 3 years. Assuming all areas affected by the cores to be similar under the same tree, approximately 22.4 to 35.2 cubic feet of soil per tree would be affected by the 16 cores per tree. This means that, under an experimental test, from 1.6 to 2.5 per cent of the total soil 13 feet away from the tree trunk and 2 feet deep has been increased from a low or very low available K content to a very high available content.

That roots would develop in this area and not be injured is worthy of note, although quantitative determinations of the root population was not attempted.

From a practical standpoint, it would mean that potash fertilizers could be dropped behind a deep tillage tool, such as a Killifer disk or coulter, to a depth of 16 to 18 inches. This would be within the active absorbing zone of the tree roots in most eastern orchard soils and also below the zone in which potassium is fixed by alternate wetting and drying. Its lateral movement should then be ample for supplying the needs of the tree.

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GEOGRAPHICAL LOCATION AND SOIL ORGANIC MATTER[1]

JACKSON B. HESTER AND F. A. SHELTON[2]

THE soil is a complicated natural body, the chemical elements and compounds of which are influenced by climatic conditions (7, 8, 9).[3] The organic components of the soil are influenced by associated vegetation but are affected mostly by the two chief components of climate, namely, rainfall and temperature. The reaction (pH) of the soil and associated conditions influence the type and quantity of vegetation (5) upon the soil; therefore, the organic matter content is obviously indirectly influenced by the parent geological material from which the soil is built.

The fertility of an economic soil is largely determined by the organic matter content, due to the fact that the organic matter contains the soil nitrogen, etc., and also exhibits various other properties. Then, the destruction of the organic matter to liberate nitrogen, etc., is essential in order to realize its great value in producing crops. Again, the chief components of climate, temperature and rainfall, are important factors.

It was pointed out in a previous publication (4) that comparable data for organic matter should include only soils of a given texture and drainage. In studying the fertility factors of soil on which tomatoes or tomato plants are grown the authors have had a chance to analyze a large group of A_p soil samples[4] from various parts of the United States and Canada for the organic matter content, pH value, and various nutrient elements. These data have been assimilated according to certain textural relation and are given in this discussion. Fig. 1 shows the geographical distribution and number of samples, the mean annual temperature and rainfall, and the texture of the soil of the given sections.

VARIATION OF ORGANIC MATTER CONTENT IN SOIL IN A LONGITUDINAL DIRECTION

The predominating soil types on which tomatoes are grown in the three sections, namely, Colborne, Canada (2, 11); Burlington County, New Jersey (1, 7); and Tifton, Georgia (9), are the well-drained sandy loams. The mean annual temperature of these three sections varies from approximately 44° F at Colborne, Canada, to 52° F at Moorestown, New Jersey to 69° F at Tifton, Georgia, or an approximate variation of 25 degrees. The mean annual rainfall decreases from approximately 48 inches at Tifton to 45 inches in New Jersey to 33 inches in the Colborne section. The organic matter content of the well-drained sandy loams, as shown in Table 1, is between 2.0

[1]Contribution from the Department of Agricultural Research, Campbell Soup Company, Riverton, New Jersey. Received for publication March 10, 1939.

[2]Soil Technologist and Assistant, respectively.

[3]Figures in parenthesis refer to "Literature Cited", p. 603.

[4]Samples were collected by the field representatives in each section. Only the A_p horizon from tomato-producing soils is considered. The color and texture were classified in the laboratory by the authors on dry samples.

and 3.9% for 71% of the soils around Colborne, whereas, 59 and 69% of the soils in Burlington County and around Tifton, respectively, were in the range of 1.0 to 1.9%. In other words, for an increase of 25 degrees in temperature and 15 inches of rainfall the organic matter content in the soil dropped 1.2%. Thus, the mean organic matter content of the Canadian soils was 2.86% and of the Georgia soils

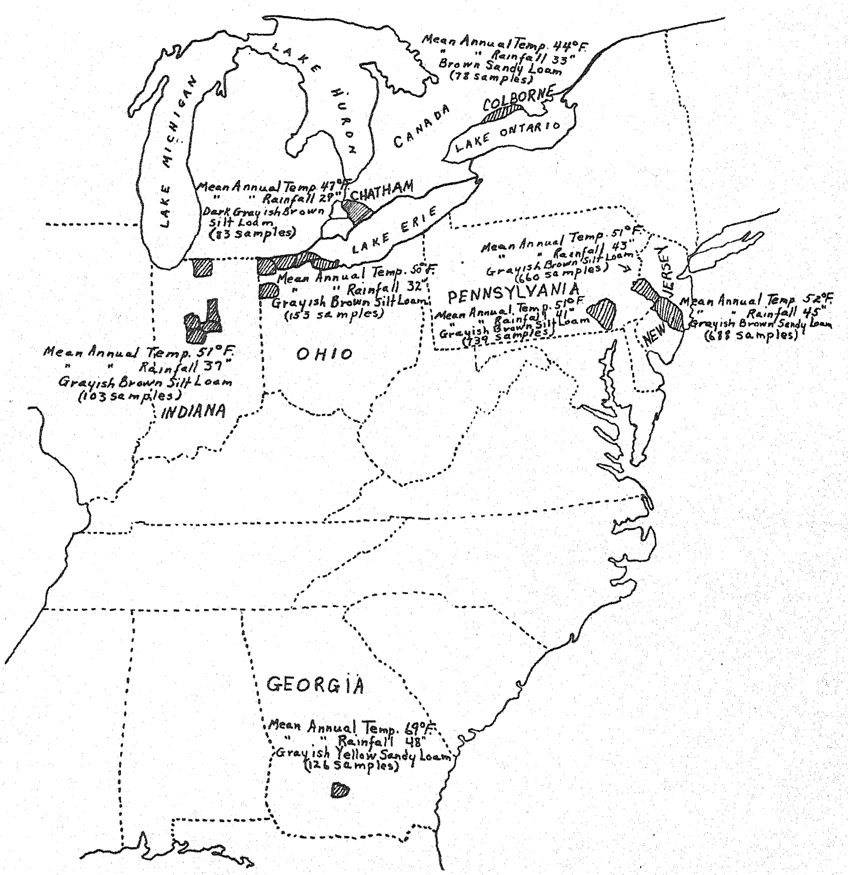

FIG. 1.—The distribution of soil samples and the mean annual rainfall and temperature of the respective areas.

1.67%. However, the fact should not be overlooked that the soils in New Jersey and Georgia were derived from non-calcareous materials while the ones in Colborne were from calcareous materials. The differences in pH values are shown in Table 2 and the differences in replaceable calcium in Table 3.

Undoubtedly, the high annual temperature and rainfall would cause the organic matter of the soils in the warmer climate to decompose faster and give up more nitrogen. This factor is perhaps largely responsible for establishing these organic matter content re-

TABLE 1.—*The influence of geographical location upon the organic matter content of sandy loam soils.*

Organic matter, %*	Percentage distribution		
	Colborne, Canada†	Burlington Co., N. J.‡	Tifton, Ga., §
–0.9	0	1	3
1.0–1.9	10	59	69
2.0–2.9	47	34	22
3.0–3.9	24	6	6
4.0–4.9	12	0	0
5.0–	7	0	0

*Organic matter determined by titration method (4).
†Predominating color of A_p horizon brown (Podsolic group). Soil type Dundonald. Parent material calcareous.
‡Predominating color of A_p horizon light brown to grayish brown (Gray-Brown podsolic group). Soil types Sassafras and Collington. Parent material non-calcareous.
§Predominating color of A_p horizon grayish yellow (Yellow soils group). Soil types Tifton and Norfolk. Parent material non-calcareous.

TABLE 2.—*The pH values of sandy loam soils in different locations.*

pH of soil*	Percentage distribution		
	Colborne, Canada	Burlington Co., N. J.	Tifton, Ga.
–4.9	0	4	1
5.0–5.4	0	35	34
5.5–5.9	3	48	51
6.0–6.4	19	11	14
6.5–6.9	31	2	0
7.0–7.4	11	0	0
7.5–7.9	36	0	0

*Glass electrode (1:2 soil-water relation).

TABLE 3.—*Replaceable calcium content of sandy loam soils in different locations.*

Replaceable CaO*	Percentage distribution		
	Colborne, Canada	Burlington Co., N. J.	Tifton, Ga.
– 499	0	13	57
500–1499	3	55	42
1500–	97	32	1

*Parts per two million (sodium acetate extract).

lations. Jenny (6) states that for every 18° F fall in temperature the nitrogen increased two or three times in the soil. From these figures the conclusion could be drawn that there is about twice as much nitrogen in Canadian soils as in Georgia soils.

SILTY LOAM SOILS

The variations in the organic matter content for the silty loam soils in Chatham, Canada (2, 11), Indiana, and Ohio are shown in Table

4. These data show that for a comparatively small change in temperature and rainfall a considerable difference in organic matter content is shown. Undoubtedly the type of agriculture and soil has influenced the organic matter content of these soils. But, perhaps again, climate has been a more predominating factor. The distribution of these soils in respect to pH is shown in Table 5.

TABLE 4.—*The influence of geographical location upon the organic matter content of silty loam soils.*

Organic matter, %	Percentage distribution	
	Chatham, Canada*	Ohio and Indiana†
–2.9	0	6
3.0–3.9	0	11
4.0–4.9	6	26
5.0–5.9	23	28
6.0–6.9	30	20
7.0–7.9	18	8
8.0–	22	0

*Predominating color of A_p horizon grayish brown (Podzolic group). Parent material calcareous. Soil types Brookston and Thames.

†Predominating color of A_p horizon grayish brown (Podzolic group). Parent material calcareous. Soil types Brookston and Toledo.

TABLE 5.—*The pH values of silty loam soils in two localities.*

pH of soil	Percentage distribution	
	Chatham, Canada	Ohio and Indiana
5.0–5.4	0	3
5.5–5.9	2	9
6.0–6.4	14	25
6.5–6.9	24	43
7.0–7.4	22	12
7.5–7.9	34	8
8.0–	4	0

VARIATION OF ORGANIC MATTER CONTENT OF SILTY LOAM SOILS IN A LATERAL DIRECTION

Across the country the chief variation in climate is in the rainfall and humidity. In studying the organic matter content of the silt loam soils in this direction, soil samples from the following localities have been analyzed: Burlington County, New Jersey (1); Bucks County, Pennsylvania (9); Lancaster County, Pennsylvania (3); Toledo, Ohio (10, 12); and northern Indiana (13). Fig. 1 gives the mean annual temperature and rainfall of each section.

The results presented in Table 6 show that 99% of the well-drained silty loam soils in Burlington County are below 2.9% organic matter, whereas in Bucks County 86% are in the 2.0 to 3.9% group with a definite tendency toward the 2.0 to 2.9% group. In Lancaster County 87% of the soils are in the 2.0 to 3.9% group, but in Ohio 63% of the soils are in the 5.0 to 6.9% group; whereas, in a slightly warmer sec-

tion of Indiana, 51% of the soils are in the 4.0 to 5.9% group. In Table 7 the pH value distribution of the soil samples is shown.

TABLE 6.—*The influence of geographical location upon the organic matter content of silt loam soils.*

Organic matter, %	Percentage distribution*				
	Burlington Co., N. J.	Bucks Co., Pa.	Lancaster Co., Pa.	Ohio	Indiana
1.0–1.9	48	14	8	0	3
2.0–2.9	51	63	55	0	13
3.0–3.9	1	23	32	6	19
4.0–4.9	0	0	5	22	30
5.0–5.9	0	0	0	34	21
6.0–6.9	0	0	0	29	8
7.0–7.9	0	0	0	10	6

*Predominating soil type in Burlington Co., N. J., Sassafras (including loams); Bucks Co., Pa., Penn (including loams); Lancaster Co., Pa., Hagerstown and Conestoga; Ohio, Toledo; Indiana, Brookston.

TABLE 7.—*The pH values of silty loam soils in various localities.*

pH of soil	Percentage distribution				
	Burlington Co., N. J.	Bucks Co., Pa.	Lancaster Co., Pa.	Ohio	Indiana
–4.9	8	7	0	0	0
5.0–5.4	38	26	3	2	4
5.5–5.9	36	30	31	6	14
6.0–6.4	15	22	53	23	29
6.5–6.9	3	10	12	47	37
7.0–7.4	0	5	0	14	9
7.5–	0	0	0	8	7

The difference in rainfall and humidity has influenced the amount of organic matter found in the soil in Burlington County, but perhaps the type of agriculture accounts for some decrease. Perhaps, longitudinally the temperature has been the predominating factor, whereas latitudinally rainfall has been the outstanding influence. It should be further pointed out that as one goes west to Ohio from New Jersey the silty loam soils become heavier. That is, soils in Burlington County just come into the silty loam class, whereas the ones in Ohio are tending to become clays. There was much more clay in the soils from Ohio and Indiana than in the ones from New Jersey and Pennsylvania.

DISCUSSION

The economic importance of organic matter in the soil has been fully appreciated and emphasized. Its destruction and incorporation in the soil has perhaps been overlooked. Owing to the difference in temperature more organic matter is probably necessary in a colder than in a warmer climate to furnish an equal amount of nitrogen for

crop growth. While the data in this paper are greatly lacking in what influence man has had in changing the organic matter content of the soil, they show the variations in the different sections and their probable relation to climate.

SUMMARY

Data are given to show the organic matter content and pH value of certain soils in various sections of the United States and southern Canada. Attention has been called to the variation in climatic conditions in the sections considered.

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EFFECT OF DIFFERENT TEMPERATURES ON THE GERMINATION OF SEVERAL WINTER ANNUAL SPECIES OF TRIFOLIUM[1]

E. H. TOOLE AND E. A. HOLLOWELL[2]

THROUGHOUT the southern, south central, and Pacific states many winter annual Trifolium species, such as *T. dubium*, least hop clover, *T. procumbens*, low hop clover, *T. resupinatum*, Persian clover, *T. subterraneum*, subterranean clover, and *T. glomeratum*, cluster clover, are perpetuated from year to year by self-seeding in early summer and volunteering during the fall months. This occurs, however, to a degree making these clovers of agricultural importance only after a seed equilibrium has been established in which germinable seed are present in sufficient numbers to produce good stands. The seed coats of nearly all these species are "hard", making them impermeable to moisture; therefore, they must be scarified either through the action of weathering or by abrasion. Others are relatively "soft seeded" and will germinate without scarification. Under natural conditions it is believed that most of the "hard" seed is softened by the weathering process and is germinable during the spring and summer months. However, plants of these species are conspicuously absent from the flora during the summer months. Most seed of crimson clover, *T. incarnatum*, another winter annual, will germinate when planted or from volunteer seeding at any time during the summer. In the southern states insufficient moisture is not often a limiting factor in germination during this period.

This study, a phase of a life history project of the Division of Forage Crops and Diseases, was designed to determine the effect of different temperatures on germination under laboratory conditions where the control of temperatures is possible. High summer soil temperatures may be responsible for live permeable seed remaining dormant until fall or until the occurrence of cool weather.

METHODS

During June 1935, seed of low hop clover, Persian clover, cluster clover, and buffalo clover, *T. reflexum*, was gently hand stripped from standing plants without being scarified in any way. Seed of subterranean clover was harvested by raking the buried pods from the soil and while this method of harvesting might scarify some of the seed, facilities did not permit other treatment. The seed was hulled by gently rubbing it in the palm of the hand. Each seed lot was divided into two parts, one part was scarified by rubbing the seed between sand paper while the other part was not scarified.

The seeds were stored in small paper envelopes in the laboratory and monthly germination tests were made beginning July 1935 and continuing through February 1936, for the scarified seed of Persian clover, cluster clover, and buffalo clover, and through December 1935 for the unscarified seed of the above three

[1]Contribution from the Divisions of Seed Investigations and Forage Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture. Received for publication March 17, 1939.

[2]Physiologist and Senior Agronomist, respectively.

species and for both lots of low hop clover. Only enough seed was available for three tests of each lot of subterranean clover. Additional tests were made in September 1937 and July 1938 of all lots except subterranean clover.

Duplicate tests, using 100 seeds each, were made between moistened blotting paper at 35°, 30°, 25°, 20°, 15°, and 10° C in germination chambers maintained within 1° C of the stated temperature. The tests at 5° C were kept in a refrigerator where the temperature varied from 3° to 6° C. The tests were continued for 28 days, except for the first two months, when the tests at some of the higher temperatures were transferred to lower temperatures after 21 days.

The viability of the scarified seed had declined before the 1937 and 1938 tests were made and, therefore, these results are not included in the averages of the germination at the different temperatures but are given to indicate the rate of loss of viability under laboratory storage.

RESULTS

The results of the germination tests for all five species are presented in Tables 1 and 2, but the results for each species will be discussed separately.

PERSIAN CLOVER

Scarified seed.—Scarification of this sample was nearly complete so that practically no hard seed remained. Germination was essentially the same at the four temperatures 25°, 20°, 15°, and 10°, except for the first test at 25°. Germination at 30° and at 35° was variable, but in all cases appreciably lower than at 20°. The unfavorable effect of the higher temperatures, 35° and 30° and to some extent 25°, is shown by the comparatively low germination during the first 6 days in comparison with the almost complete germination during this period at 20°, 15°, and 10°. Germination at 5° was somewhat erratic which fact will be explained in the general discussion. After two and especially after three years, loss of viability of the seed was considerable.

Unscarified seed.—No appreciable loss of viability of the unscarified seed was observed after 3 years. During the early months of the experiment a few seed absorbed water, but differences in germination at different temperatures were not evident. Beginning with the November 1935 test, however, a gradual softening of the hard seeds occurred and this, as shown graphically in Fig. 1, was progressively greater at the lower temperatures.

CLUSTER CLOVER

Scarified seed.—Germination of this species for the first 8 months was essentially the same at the three temperatures 20°, 15°, and 10°. During the early months, germination at 25° averaged decidedly lower than at 20°, but in October it was as high at 25° as at the lower temperatures. Germination was markedly lower at 30° and 35°. The progressive change of germination of the seed in this sample at 20°, 25°, and 30°, as shown in Fig. 2, is hard to explain, unless it was influenced by changes in the humidity of the laboratory where the seed was stored. As with the preceding species, the differences at the

TABLE I.—*Average percentage germination and percentage hard seed in 28 days of successive tests of scarified samples of five species of Trifolium.*

Germination temperature, °C	1935												1936				Average of all tests in 1935 and 1936		1937		1938	
	July		August		September		October		November		December		January		February				September		July	
	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed
											Persian Clover											
35	—	—	51*	0	81	0	74	0	72	0	82	0	76	0	91	0	75.3	0	64	0	31	0
30	66*	0	78	0	80	0	80	0	60	0	61	0	73	0	84	0	72.8	0	—	0	48	0
25	76	0	97	0	98	0	97	0	98	0	91	0	95	0	96	0	93.5	0	76	0	62	0
20	94	1	99	0	98	0	96	0	97	0	96	0	97	0	97	0	96.8	0	88	0	65	0
15	92	0	94	0	97	0	97	0	97	0	98	0	97	0	98	0	96.3	0	86	0	55	0
10	97	0	97	0	94	0	96	0	97	0	92	0	97	0	94	0	95.5	0	81	0	46	0
5	95	1	88	0	95	0	90	0	89	0	83	0	91	0	81	0	89.0	0	52	0	40	0
Av.......	86	0	86	0	91	0	90	0	87	0	86	0	89	0	91	0						
											Cluster Clover											
35	—	—	5*	15	16	12	22	9	17	12	8	9	7	8	9	11	12.0	10.9	2	15	6	19
30	19*	20	8*	19	42	14	39	12	16	12	18	11	18	14	21	14	22.6	14.5	—	14	23	10
25	22	16	48	11	69	13	84	10	75	11	56	15	43	10	47	15	55.5	12.6	57	14	58	21
20	74	24	78	17	83	12	86	12	84	12	82	17	78	17	77	19	80.3	16.3	67	23	66	23
15	68	29	76	21	83	15	80	19	76	18	78	21	79	19	78	20	77.3	20.3	67	27	55	21
10	75	25	81	19	78	13	80	19	75	18	74	22	75	19	67	28	75.6	20.4	62	29	59	21
5	65	32	69	25	56	24	68	21	66	21	69	28	40	31	33	35	58.3	27.1	42	32	48	26
Av.......	53	24	52	18	61	14	65	14	58	14	55	17	48	16	47	20						

Buffalo Clover																						
35	—	—	5*	10	9	7	10	7	3	11	—	—	3	6	.6	8	6.0	8.2	2	9	4	8
30	17*	8	9*	7	51	8	32	9	21	7	27	11	42	4	58	7	32.1	7.6	—	17	40	12
25	51	6	72	5	82	11	91	6	86	10	90	10	88	11	87	9	80.9	8.5	68	15	50	13
20	87	8	91	8	87	11	87	11	88	12	84	13	90	8	84	15	87.3	10.8	71	12	53	15
15	86	12	85	14	89	9	91	7	87	11	84	14	90	9	87	11	87.4	10.9	55	15	45	15
10	83	16	86	13	88	10	87	10	89	11	86	13	86	12	87	12	86.5	12.1	56	15	49	19
5	81	11	78	14	72	14	88	9	75	15	75	13	34	11	31	22	66.8	13.8	38	15	31	15
Av.......	67	10	60	10	68	10	69	8	64	11	74	12	61	8	62	12						
Subterranean Clover																						
30	0*	1	4*	4	12	6	—	—	—	—	—	—	—	—	—	—	5.3	3.7	—	—	—	—
25	4	1	6*	2	6	2	—	—	—	—	—	—	—	—	—	—	5.3	1.7	—	—	—	—
20	97	2	98	1	97	3	—	—	—	—	—	—	—	—	—	—	97.3	2.0	—	—	—	—
15	95	4	95	4	91	6	—	—	—	—	—	—	—	—	—	—	93.7	4.7	—	—	—	—
10	95	3	96	2	93	4	—	—	—	—	—	—	—	—	—	—	94.7	3.0	—	—	—	—
5	94	4	93	5	95	3	—	—	—	—	—	—	—	—	—	—	94.0	4.0	—	—	—	—
Av.......	64	2	65	3	56	4	—	—	—	—	—	—	—	—	—	—						
Low Hop Clover																						
35	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	30	0	35
30	0*	30	0*	30	1	25	1	32	1	24	1	37	—	—	—	—	0.7	29.7	2	29	0	—
25	2	34	1*	24	9	22	3	31	12	32	5	31	—	—	—	—	5.3	29.0	2	30	1	38
20	62	36	59	41	62	33	65	33	65	29	62	34	—	—	—	—	62.5	34.3	32	44	48	39
15	59	39	60	36	66	32	60	38	59	40	64	34	—	—	—	—	61.3	36.5	54	35	50	36
10	67	32	51	49	49†	33	59	38	64	32	62	36	—	—	—	—	58.7	36.7	63	28	49	41
5	53	47	52	46	50	41	47	44	37	44	26	44	—	—	—	—	44.3	44.3	24	45	25	42
Av.....	40	36	37	37	39	31	39	36	39	33	36	36	—	—	—	—						

*Germination and hard seed at 21 days instead of 28 days.
†14% watery abnormal seedlings.

									Buffalo Clover									
35	—	—	—	—	—	—	—	—	—	—	—	—	0	96	1	95		
30	0	97	0	97	4	94	2	95	2	95	1	94	1	97	0	96	1.3	95.6
25	2	92	2	95	3	95	3	96	5	92	3	96	1	97	1	97	2.5	95.0
20	3	96	2	97	4	94	5	94	3	95	3	96	2	96	1	98	2.9	95.6
15	3	95	1	97	4	96	4	94	3	95	2	96	1	97	1	97	2.4	95.9
10	2	93	3	94	3	95	2	97	2	98	3	95	0	96	1	96	2.0	95.5
5	1	97	2	95	2	97	2	95	1	97	0	96	0	96	0	98	1.0	96.4
Av.*....	2	95	2	96	3	95	3	95	3	95	2	96	1	97	1	97		
									Subterranean Clover									
30	1	43	1	39	0	39	—	—	—	—	—	—	—	—	—	—	0.7	40.3
25	0	36	2	39	1	37	—	—	—	—	—	—	—	—	—	—	1.0	37.3
20	62	37	53	46	63	34	—	—	—	—	—	—	—	—	—	—	59.3	39.0
15	62	37	55	44	57	41	—	—	—	—	—	—	—	—	—	—	58.0	40.7
10	46	48	60	37	57	41	—	—	—	—	—	—	—	—	—	—	54.3	42.0
5	59	39	59	39	55	41	—	—	—	—	—	—	—	—	—	—	57.7	39.7
Av.....	38	40	38	41	39	39	—	—	—	—	—	—	—	—	—	—		
									Low Hop Clover									
35	—	—	—	—	—	—	—	—	—	—	—	—	0	85	0	87	—	—
30	0	81	0	88	0	83	0	80	0	83	0	80	0	82	0	84	0.0	82.6
25	0	84	0	87	0	89	0	88	1	88	2	84	0	83	0	82	0.4	85.6
20	9	89	5	94	5	93	10	88	7	92	12	86	13	81	6	89	8.4	89.0
15	9	89	9	90	9	90	7	91	6	93	18	81	20	79	16	80	11.8	86.6
10	7	91	10	89	14	84	13	86	24	74	21	77	30	64	12	84	16.4	81.1
5	4	95	11	88	10	83	9	89	3	91	3	82	6	74	8	77	6.8	84.9
Av.*....	5	88	6	89	6	87	7	87	7	87	9	82	12	77	7	83		

*Readings at 35° not included in averages.

various temperatures were even more marked when the results at the end of 6 days are compared. Table 3 shows that germination at 5° was low, accounted for, in part, by the increased number of hard seed at this temperature. The average percentage of hard seeds for the first 8 months for different temperatures of germination showed in general a larger number of hard seeds remaining as the temperature

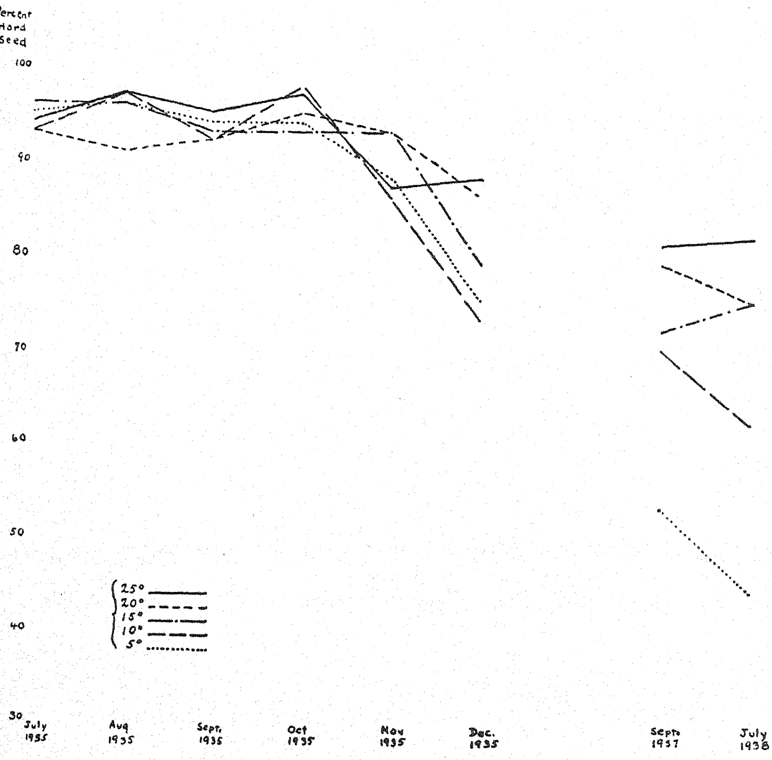

FIG. 1.—Effect of age on percentage of hard seed in a nonscarified sample of Persian clover seed when germinated at different temperatures.

was lowered. A considerable difference in the number of hard seed occurred during the different months of test. This variation was in general inversely proportional to the progressive changes in germination at 20° illustrated in Fig. 2.

Unscarified seed.—Over the entire period of the test the unscarified seed of this species did not show striking or consistent variations in germination or hard seed content.

BUFFALO CLOVER

Scarified seed.—At 25° germination increased progressively for the first four months in contrast to the essentially uniform germination at 20°, 15°, and 10°. This progressive improvement in germination at

25° is especially marked when the results at 6 days are compared, as shown in Table 3. Germination was much lower at 30° and at 35°. As shown in Fig. 3, wide unexplained progressive fluctuations of germination occurred at 30°. At 5° germination was often accompanied by the development of watery seedlings. It was apparent that 5° was too low a temperature for the development of normal seedlings of this species.

TABLE 3.—*Average percentage germination in 6 days of successive tests of scarified samples of three species of Trifolium.*

Germination temperature, °C	Percentage germination							
	July 1935	Aug. 1935	Sept. 1935	Oct. 1935	Nov. 1935	Dec. 1935	Jan. 1936	Feb. 1936
				Persian Clover				
35	—	5	4	3	7	3	1	2
30	13	10	48	22	18	9	26	24
25	32	84	95	85	91	52	70	96
20	94	99	98	96	97	96	97	97
15	91	94	97	97	97	98	97	98
10	95	97	94	96	97	92	88	93
5	80	72	0	0	0	0	0	0
				Cluster Clover				
35	—	2	1	4	2	1	1	1
30	0	0	2	8	2	0	1	2
25	0	4	16	47	40	1	7	8
20	58	67	75	79	72	69	61	67
15	53	65	75	70	68	65	69	67
10	62	72	68	69	62	58	53	50
5	31	22	0	0	0	0	0	0
				Buffalo Clover				
35	—	0	1	0	0	—	0	0
30	0	1	21	2	10	13	29	4
25	5	30	66	87	80	81	79	82
20	82	87	85	85	85	82	85	79
15	78	81	88	89	85	81	87	84
10	74	81	84	85	86	82	63	57
5	0	0	0	0	0	0	0	0

With this species the mean hard seed content at the different temperatures of germination shows differences, some of which are significant. As with cluster clover, there is an increased number of hard seed at the lower temperatures, although the difference between the upper and lower temperatures is not great.

After two and three years storage a decided fall in germination and a slight increase of hard seeds were observed.

Unscarified seed.—As with cluster clover the unscarified seed did not vary appreciably in germination or hard seed, either at the different temperatures or for the different months of the test.

SUBTERRANEAN CLOVER

Scarified seed.—This species showed a sharp response to temperature of germination. Germination was high at 20° and at all the lower

temperatures but was almost negligible at 25° and 30°. At these temperatures the seeds were swollen but remained dormant. Comparative tests at 20° and 25° with a number of other samples of this species

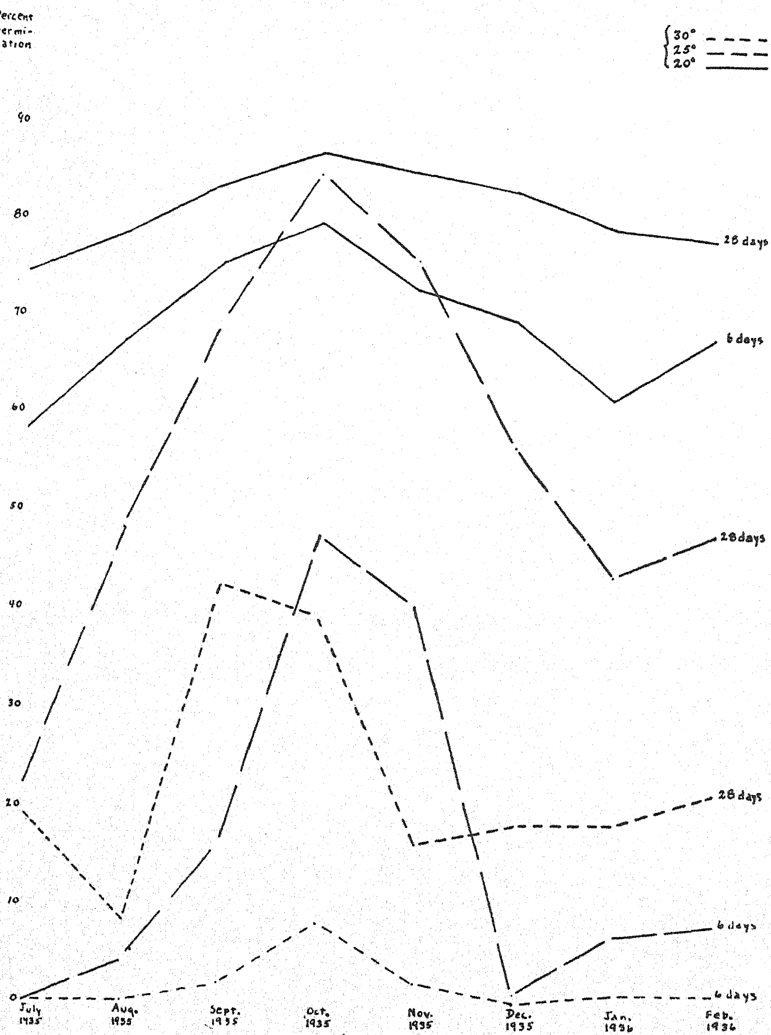

FIG. 2.—Comparison of germination percentages for 6 and 28 day periods of successive monthly tests of scarified cluster clover seed when germinated at temperatures of 20°, 25°, and 30° C.

have shown the same temperature response. At the favorable temperatures germination was practically completed in 6 days.

Unscarified seed.—At favorable temperatures the germination of this sample was above 50%. Since this sample was not hand harvested

it is not known whether the germinating seed represented naturally "soft" or scarified seed. The same sharp response to temperature differentials is shown as with the scarified seed.

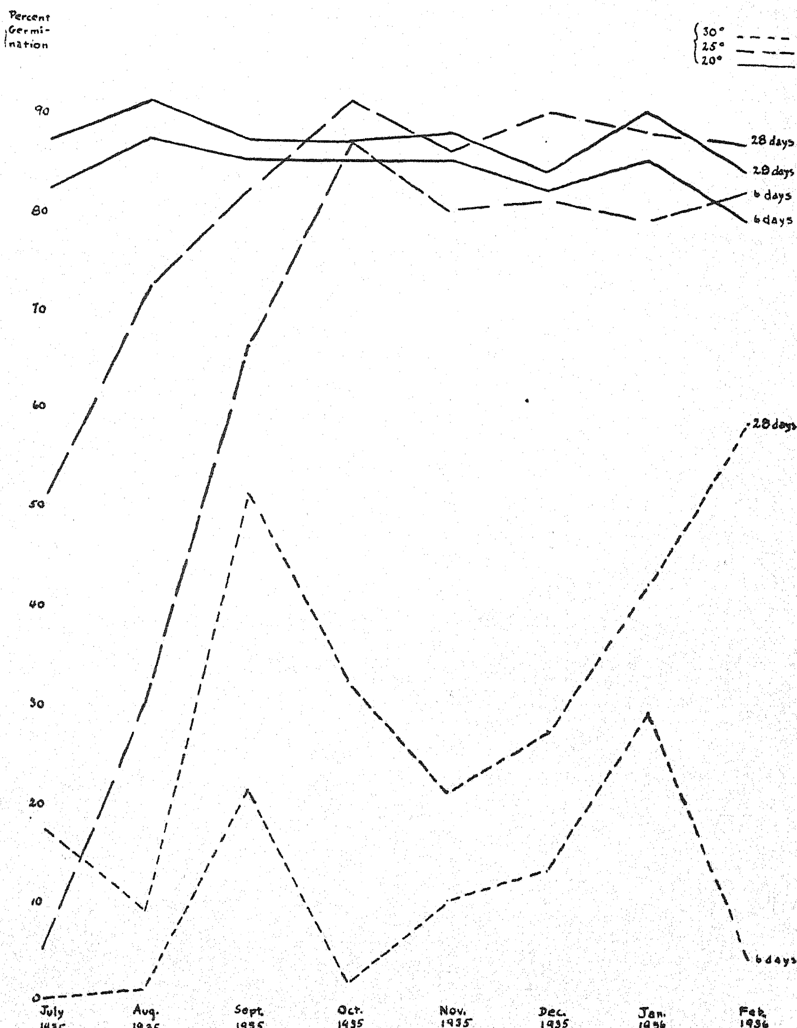

FIG. 3.—Comparison of germination percentages for 6- and 28-day periods of successive monthly tests of scarified buffalo clover seed when germinated at temperatures of 20°, 25°, and 30° C.

LOW HOP CLOVER

Scarified seed.—Scarification of the very small seed of this species was not at all complete. This species also shows a striking germination response to temperature. At 25° and 30° germination was very

low, but was essentially the same at 20°, 15°, and 10°. As with buffalo clover, 5° was too low for development of normal seedlings.

As with cluster clover and buffalo clover, the hard seed increased in number with lowered germination temperatures. The loss of viability after 2 and 3 years is not as marked as for some of the other species.

Unscarified seed.—Although the percentage of seeds that absorbed water was comparatively low, the same sharp difference in germination was evident in seed tested at 25° and 20°. A tendency for an increased softening of the hard seeds at the lower temperatures is shown especially at 10°, but the results are not consistent enough to consider this tendency significant.

CRIMSON CLOVER

Unscarified seed.—In 1938 a small sample of crimson clover seed was hand harvested and germinated without scarification at the same temperature differentials as used for the other species. Approximately 50% of the seed took up water and germinated and no significant difference in germination at different tempeatures was apparent. At a temperature of 35° C fewer seed remained hard and at 30° germination was somewhat slower than at 25° and below.

DISCUSSION

LABORATORY GERMINATION

Of the five species under study, subterranean clover and low hop clover showed the sharpest differences in germination at different temperatures. Both species germinated well at 20° or lower, but at 25° or higher germination was very low.

Buffalo clover germinated as well at 25° as at 20° and even at 30° germination averaged 30% for the 8 monthly tests. The response of cluster clover was somewhat similar to that of buffalo clover except for the excessive variation at 25° for the different months. Persian clover was least affected by temperature of germination, although considerable variation was evident in the monthly results. This species averaged more than 70% germination at both 30° and 35° for the first 8 months tested, but germination was much slower than at the lower temperatures.

No significant variation in germination was apparent in the successive monthly tests at 20°, 15°, and 10° of the scarified seed of Persian clover, buffalo clover, subterranean clover, and low hop clover. Germination at 25° tended to increase during the first three months of test for Persian clover, cluster clover, and buffalo clover, which may indicate dormancy at high germination temperatures immediately after harvest. This condition lasted for a period of from one to three months.

The germination of cluster clover seed tested at 20° and 25° consistently increased until October and then gradually decreased. The change at 30° was similar but germination at all times was much lower. As previously stated these changes are in part reflected in the monthly averages of hard seed for this species. The other species did not show this subsequent reduction in germination.

The four species tested in September 1937 and in July 1938 showed a more or less marked reduction in viability of the scarified samples, but no definite change in response to temperature.

Because of the slow germination at the higher temperatures and at 5° the tests were continued for 28 days. At 20° very little increase of germination occurred after 6 days, but at the higher temperatures a great deal of the germination occurred after this time. Table 3, showing the comparative germination at 6 days, emphasizes the difference in rate of germination at the various temperatures. This table also emphasizes the progressive improvement in germination of Persian clover and buffalo clover for the first months at 25°. Since subterranean clover and low hop clover germinated very poorly at the higher temperatures, these species are not included in Table 3.

The refrigerator, used for the temperature designated as 5°, varied in temperature more than the other chambers. This temperature variation accounts in part for the erratic results at 5°. Also, the seedlings of cluster clover, buffalo clover, and low hop clover produced at this low temperature were stunted and watery. Considerable variation existed in interpreting the condition of these sprouts in the different tests. Persian clover and subterranean clover produced fairly normal seedlings at this low temperature.

It has been suggested by Davis[3] that some kinds of seeds held moist at a temperature too high for germination are thrown into secondary dormancy after which a lower than normal temperature is required for germination. In conducting the first two series of tests, the seeds which did not germinate in 21 days at 30° and 35° were transferred to 20° and to 10°. In general the germination of the sound seed was prompt and complete at both temperatures. However, with low hop clover germination was much quicker when the seeds from a high temperature were transferred to 10° than when transferred to 20°, indicating a possible secondary dormancy after holding the moist seed at a high temperature.

As previously stated, there was in the scarified samples of cluster clover, buffalo clover, and low hop clover a significant difference between the average hard seed content of seed germinated at low and high temperatures. The tendency was for a greater number of hard seed to germinate at the lower than at the higher temperatures which is in striking contrast to the tendency in the unscarified sample of Persian clover where, during the later months, less hard seed occurred at the low temperatures. Since practically no hard seeds were present in the scarified sample of the latter species, a direct comparison of the behavior of the hard seeds of scarified and non-scarified samples is impossible.

RELATIONSHIPS OF SOIL TEMPERATURES TO FIELD GERMINATION

In attempting to correlate the results of these studies with field

[3]Davis, W. E. Primary dormancy, after ripening and the development of secondary dormancy in embryos of *Ambrosia trifids*. Amer. Jour. Bot., 17:58–76. 1930.

————. The development of dormancy in seeds of cocklebur (Xanthium). Amer. Jour. Bot., 17:77–87. 1930.

behavior, other ecological factors such as moisture, soil type, and the amount of solar energy are either directly or indirectly related to soil temperatures. Furthermore, under natural conditions, diurnal variation in surface soil temperatures is often very great. The extent of its effect on germinating seed is not known. With the exception of subterranean clover the seeds of the species studied are very small and the seeds must be on or near the soil surface for germination. The surface soil temperatures are therefore most important for the small-seeded species and temperatures one-half inch under the surface for the larger seeded species. So far as known continuous soil temperature records for the surface or slightly thereunder have not been taken in the southern states. In connection with other investigations continuous soil temperature records were taken at Columbia, Mo., during the spring, summer, and fall months of 1937 at a depth of one-half inch under the soil surface and are presented in Table 4.[4] The mean air temperatures of 1937 at Columbia, Mo., for the months of March and April were slightly below the normal mean, while they were above normal for the months of May, June, July, August, and September.

Surface soil temperatures are subject to greater variation than those below the surface and for that reason the average daily maximum temperatures at the surface would doubtless be higher and would occur somewhat earlier in the spring than the temperatures as shown in the records presented in Table 4 at one-half inch below the surface. If maximum soil temperatures are used as a basis of analyses, the period May 1 to 15 would be unfavorable for the germination of low hop clover and subterranean clover but favorable for the other species. This is shown by the results of experiments in which germination of the former species was sharply inhibited at a 25° temperature level. A similar analysis of the temperature records for the fall months indicates that the period of October 16 to 31 would be the most favorable for germination. Of the species investigated low hop clover has been the only one successfully established at Columbia, Mo.

In previous date of planting experiments[5] at Statesville, N. C., stands have resulted from a single March planting; however the plants made only a meager growth, blossomed, and set seed sparingly. As shown by the results of this study response to different soil temperatures may be one of the contributing factors in species adaptation. Late spring germination of those species less sensitive to the inhibiting effects of high temperatures would occur at a time when other unfavorable factors for growth, such as length of day and competition from other plants, would be of increasing intensity. However, in the fall a decreasing gradient from high to low temperatures occurs and this provides favorable conditions. In the south soil temperatures are favorable for germination over a long period of time in the late fall and winter months and the fact that most winter annuals thrive in such an environment may indicate that a long period of exposure

[4]The authors are indebted to Dr. E. M. Brown for permission to use the records as presented in Table 4.

[5]The establishment of low hop clover, *Trifolium procumbens*, as affected by time of seeding and growth of associated grass. Jour. Amer. Soc. Agron., 30:589–598. 1938.

TABLE 4.—*Average mean and daily maximum air temperatures taken 6 inches above a Kentucky bluegrass sod and bare soil temperatures taken ½ inch below the soil surface at Columbia, Mo., 1937.*

Period	Temperatures, °C				Maximum soil temperatures in °C by days of the month*															
	Av. air	Av. max. air	Av. soil	Av. max. soil	1 16	2 17	3 18	4 19	5 20	6 21	7 22	8 23	9 24	10 25	11 26	12 27	13 28	14 29	15 30	31 31
Mar. 1–15	4	9	4	11	9	16	16	**12**	19	18	21	*11*	11	12	*10*	*11*	**1**	1	2	
Mar. 16–31	4	9	5	10	1	*12*	18	**10**	*6*	17	18	*16*	*14*	7	*2*	*1*	*6*	*8*	**8**	16
Apr. 1–15	9	14	8	14	*7*	18	*19*	**6**	**6**	19	*12*	**11**	*14*	18	21	**11**	23	—†	—†	
Apr. 16–30	13	18	11	17	—†	—†	—†	25	**14**	22	23	23	**10**	**6**	**8**	18	**10**	*22*	23	
May 1–15	14	19	16	24	*23*	**16**	**16**	*24*	23	28	28	*22*	27	29	26	*25*	*20*	*26*	*25*	
May 16–31	21	26	21	31	*28*	*29*	33	*31*	36	**23**	*27*	31	29	*30*	*26*	27	34	35	34	*36*
June 1–15	18	24	19	27	*38*	*33*	**20**	*31*	*27*	24	30	*31*	**19**	**20**	*26*	*30*	*29*	30	**23**	
June 16–30	25	31	26	36	*31*	33	33	35	33	34	35	41	41	38	41	*36*	39	36	33	
July 1–15	26	33	29	41	*38*	39	*29*	40	43	42	43	42	44	43	*39*	*37*	42	*44*	43	
July 16–31	25	31	28	40	45	*34*	38	34	38	39	41	42	*36*	34	39	41	43	46	46	43
Aug. 1–15	27	33	29	42	*36*	39	*47*	*38*	46	38	*35*	43	44	*38*	45	43	46	46	47	
Aug. 16–31	27	34	30	44	47	49	49	46	*38*	*36*	*35*	*40*	43	46	46	48	47	44	43	48
Sept. 1–15	23	31	26	39	*49*	46	*46*	40	*34*	43	42	*43*	*41*	32	37	34	37	38	*34*	
Sept. 16–30	18	26	18	29	31	31	33	33	34	31	35	**31**	**21**	23	24	26	*19*	29	32	
Oct. 1–15	14	21	16	25	34	35	**23**	**24**	32	*29*	27	*22*	*22*	25	27	*26*	*19*	18	**11**	
Oct. 16–31	11	17	11	19	**16**	**15**	*24*	*17*	*17*	**13**	**7**	13	21	22	20	20	22	26	26	23

*Plain type indicates the occurrence of 65 to 100% possible sunshine for the day indicated; italic type indicates the occurrence of 10 to 65% possible sunshine; and bold face type indicates the occurrence of from 0 to 10% possible sunshine.

†Temperature recorder was out of commission during the period April 14 to 18, inc.

with normal variations of temperature may be necessary to provide the required combination of factors favorable to germination.

Since white clover, *T. repens*, behaves principally as a winter annual in the south, high temperature may be an inhibiting factor in its germination, though observations have indicated that it is not as adversely affected by high temperatures as low hop clover or subterranean clover.

If perchance the hard seed of the species studied is softened by the effects of summer temperatures, light, and moisture after maturing in late spring, high soil temperatures, as shown by these studies, would undoubtedly inhibit its germinating until fall.

SUMMARY

Seed of low hop clover, cluster clover, subterranean clover, Persian clover, and buffalo clover was hand harvested, separated in two parts, one of which was scarified and the other left unscarified. Samples from both scarified and unscarified seed of each species were germinated under controlled laboratory conditions at temperatures of 35° C, 30° C, 25° C, 20° C, 15° C, 10° C, and 5° C, for 28-day periods at monthly intervals beginning in July and continuing for 8 months and after 2 and 3 years. Unscarified seed of crimson clover hand harvested was germinated for one period at the above temperature differentials. Percentages of germination and hard seed are reported after 6 days in test and at the end of the 28-day period.

SCARIFIED SEED

The germination of the scarified seed of all species studied was inhibited in varying degrees by the temperatures of 30° and 35° C.

At 20° and at the lower temperatures subterranean clover and low hop clover germinated well, while at 25° the germination was very low.

The germination of cluster clover was appreciably lower at 25° than at 20° except for the October and November tests. Also a marked reduction in germination occurred between the 25° and 30° and between the 30° and 35° temperatures.

Buffalo clover germinated practically as well at 25° as at 20° while at 30° a decrease in percentages from 80 to 32 occurred.

Persian clover was least affected by temperature of germination for the germination averaged more than 70% at both the 30° and 35° tests.

In general, germination at 25° increased during the first three months of test for Persian clover and buffalo clover, while for cluster clover the increase occurred through October but after November a definite decrease occurred. This reduction in germination did not occur for Persian clover and buffalo clover.

A marked reduction in the viability of the seed of the four species tested had occurred when germinated in September 1937 and in July 1938.

At the 5° temperature the sprouts of cluster clover, buffalo clover, and low hop clover were somewhat stunted and watery while those of the Persian clover and subterranean clover appeared normal.

After 21 days swollen non-germinating seed at the 30° and 35° tests for the first two months were transferred to the 20° and 10° chambers where germination was rapid and complete at either temperature for all species except low hop clover. The swollen seeds of this species germinated much faster when transferred to 10° than 20° indicating a dormancy induced by the high temperature.

UNSCARIFIED SEED

The hard seed content of the unscarified seed of the five species studied was not affected by the temperature gradients or period tested except Persian clover. Beginning with the November test a gradual softening of the hard seed of Persian clover occurred and this was progressively greater at the lower temperatures and was the most pronounced after the second and third year.

The one test with crimson clover seed made three months after harvest indicated that a high percentage of the seed was soft and that there was no significant difference in germination at the different temperatures.

An analysis of continuous soil temperature records taken at Columbia, Mo., and the results of these germination studies at different temperatures clearly show that high summer soil temperatures inhibit the germination of the species studied except crimson clover.

IDENTIFICATION OF STANDARD AND FAIRWAY STRAINS OF CRESTED WHEATGRASS[1]

W. D. Hay[2]

CRESTED wheatgrass, *Agropyron cristatum* (L.) Beauv., has spread rapidly in Montana and other western states during recent years. It is a hardy drought-resistant grass particularly valuable for dryland pasture and has been extensively used for re-grassing abandoned cultivated lands. Two strains, S.P.I. 19537 and Saskatchewan 1350, known respectively as Standard and Fairway, are grown and handled commercially. Because of their different adaptations and uses, it is often necessary to distinguish between these two strains in order to detect substitutions or mixtures.

Studies have been made of the comparative morphology of the seeds, of plants in the seedling stage, and of headed plants in the field during the past 3 years. In making this study, approximately 500 seed samples were examined, 100 seedling plants were studied, and observations were made in 80 registered crested wheatgrass fields in many parts of Montana.

IDENTIFICATION OF SEEDS

The seeds of Standard and Fairway crested wheatgrass differed in size, shape, weight, percentage of awned seed, and enclosure of the palea by the lemma. When these differences were considered, it was possible to make reliable identifications and approximate separations of mixtures. Percentages given refer to the proportion of the seed examined.

1. Size

   Length in millimeters not including the awn

   Standard: More than 6 mm, 68%; 6 mm, 28%; and less than 6 mm, 4%.

   Fairway: More than 6 mm, 6%; 6 mm, 56%; and less than 6 mm, 38%.

   Average width in millimeters

   Standard: 1.00

   Fairway: 0.75

   Observations have shown that seeds grown under adverse conditions, or from certain cleaning separations, may be somewhat reduced in length. However, under such circumstances, Standard seeds maintained a greater width and it was usually possible to distinguish between the two strains by careful observations.

2. Awns

   Presence on seeds

   Standard: Present on 14 to 55%, average 30%.

   Fairway: Present on 50 to 88%, average 70%.

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[1]Contribution from Montana State College, Agricultural Experiment Station, Bozeman, Mont. Paper No. 123, Journal Series. Received for publication March 20, 1939.

[2]Seed Analyst.

Length of awns in millimeters

Standard: Less than 0.5 mm to more than 4.0 mm, average 2.0 mm.

Fairway: Range from 2.5 mm to 4.0 mm, average 3.0 mm.

In threshing, the awns of the Standard strain tended to break off entirely or partially more easily than those of Fairway. This difference in the percentage of awned seeds and length of awns was strikingly apparent when samples of the two strains were compared.

3. Shape

Standard: 70% tapering

Fairway: 72% boat-shaped

This difference was not clearly defined but was of assistance in making analytical separations of the two strains.

4. Enclosure of palea

Standard: Lemmas fitted closely over edges of palea almost covering veins on which the teeth occurred in 72% of the seed.

Fairway: Lemma rarely extended to toothed palea veins except in immature seed.

This difference was not always pronounced but in connection with other characters was of assistance in identifying certain seeds. A hand lens or microscope was necessary for this determination.

5. Weight

Standard: Average weight of 1,000 seeds was 2.41 grams.

Fairway: Average weight of 1,000 seeds was 1.38 grams.

One thousand seeds of the heaviest Fairway sample weighed 1.56 grams. This was 0.16 gram less than 1,000 seeds of the lightest standard sample taken from a lot of screenings. The difference in the weight of Standard and Fairway seeds was normally a reliable means of distinguishing between the two strains. The differences between the seeds of the two strains are shown in Fig. 1.

IDENTIFICATION OF PLANTS

Plants of the two strains were studied in the seedling stage and during the period from heading to maturity. The important differences observed were as follows:

I. Seedling stage (percentages refer to the proportion of the plants examined)

1. Upper surface of leaves

Standard: Fine leaf-hairs usually thinly scattered, 24% of plants. Remainder glabrous.

Fairway: Fine leaf-hairs found on 100% of plants. Thinly scattered on some plants.

2. Auricles

Standard: Present on 46%.

Fairway: Present on 84%.

The auricles varied from clawed to wanting but were generally more prominent and longer on the Fairway. Auricles tended to dry up and break off as the plants approached maturity. This character, therefore, was not reliable after the leaf sheath edges began to dry up.

3. Leaf-sheath spines
   Standard: Present at sides of collar or along edge of leaf-sheath on 81% of plants.
   Fairway: Not present.

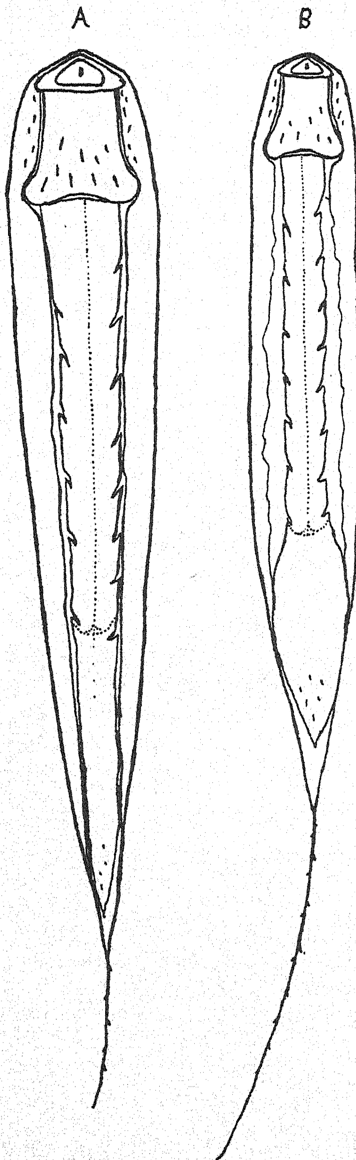

FIG. 1.—Crested wheatgrass seeds (X 20). A, Standard; B, Fairway. Differences in size, shape, awns, and enclosure of the seed by the lemma are shown.

These coarse hairs or spines tended to drop off as the plants approached maturity but were a better character for identification than the auricles.

The seedling studies were made on plants grown in the greenhouse. Plant height measurements and leaf counts were made at 3-day intervals for 42 days after emergence. During this period little difference was observed in the height and in the number of leaves per plant. Stems were cut from the greenhouse plants for binocular microscope observation 65 days after planting. At this stage the plants had begun to stool, having two or more stems and six or more leaves per plant. The differences in seedling characters are illustrated in Fig. 2.

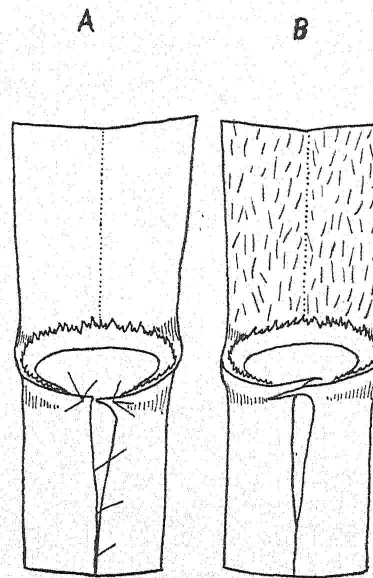

FIG. 2.—Crested wheatgrass ligule area (X 10). A, Standard; B, Fairway. Fine hairs on upper leaf surface of Fairway and coarse hairs on leaf sheath of Standard are shown.

II. Headed plants

1. Variability in height and coarseness

Standard: Stems varied greatly in height, coarseness, and number per plant (Fig. 3).

Fairway: Stems more uniform in height and number. Usually finer, more stems per plant and medium height.

2. Color

Standard: Plants varied from dark green to grayish green.

Fairway: Plants usually bright green.

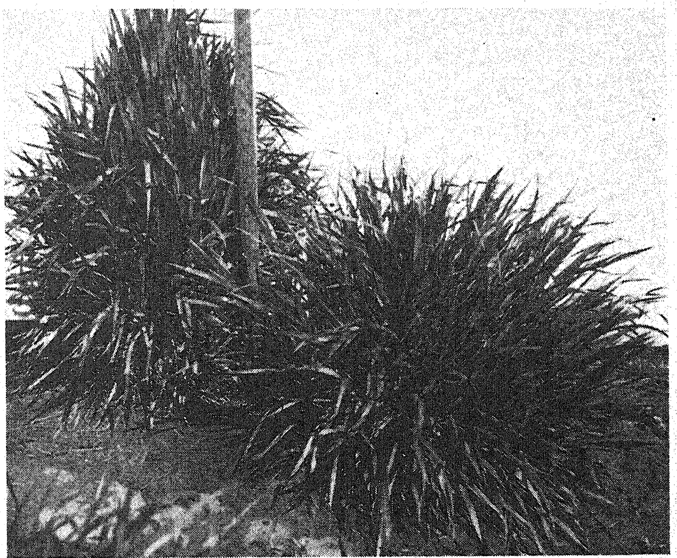

FIG. 3.—Showing variation in growth of individual plants of the Standard strain.

3. Spikes

Standard: Variable; tapering or cylindrical, twisted or straight, erect or nodding, large or small (Fig. 4).

Fairway: Broad at base and tapering toward tip.

4. Awns

Standard: Varied in length from less than 0.5 mm to more than 5.0 mm. Some spikes were awnless.

Fairway: Usually longer than on standard and less variable. Average 3.0 mm in length.

5. Upper surface of leaves

Standard: Hairs present on but few plants, usually thinly scattered.

Fairway: Long, fine hairs present on practically all plants. In the field the best time to observe the above differences in the headed plants was shortly before the bloom stage when the variability of the Standard strain was more pronounced.

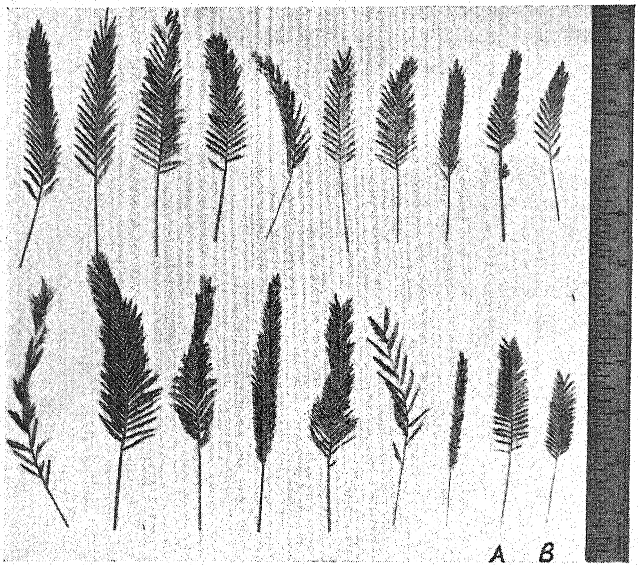

FIG. 4.—Head types of crested wheatgrass. A and B, Fairway strain; remainder Standard strain.

Fairway being a selection was less variable in all characters. Hairs on the upper leaf surface were best seen in the field by rolling the leaf over the finger and holding it toward the sun. As the plants approached maturity, distinction between the two strains became more difficult.

SUMMARY

Seeds and plants of Standard and Fairway crested wheatgrass were examined to determine the differences which would furnish a means of more definitely identifying these two strains.

The differences in size, weight, shape, percentage of awned seeds, and enclosure of the palea by the lemma made it possible to distinguish the two strains and determine the approximate percentage of each in mixtures of seed.

Identification was most difficult in the seedling stage but plantings of the two pure strains were identified by the presence or absence of leaf-hairs, hairs on the leaf sheath edges, and auricles.

Field plantings of the two strains were most easily distinguished just before blooming. At that stage of growth, the differences in the size and shape of the spikes and the variations in the height and color of standard plants were most pronounced as contrasted with the greater uniformity of Fairway. These variations furnished the best means of distinguishing between the two strains in the field.

THE EFFECT OF CULTIVATION AND EROSION ON THE NITROGEN AND CARBON OF SOME KANSAS SOILS[1]

J. C. HIDE AND W. H. METZGER[2]

HORIZONTAL or contour cultivation was recognized in the United States as a desirable practice for erosion control by Randolph, and advocated by Jefferson, before the year 1800. This method of cultivation has not been generally used by farmers, and until very recently was not extensively advocated by agricultural specialists. Experimental field work on the desirability of the practice is of recent origin.

EXPERIMENTAL PROCEDURE

In an effort to compare cultivation across the slope with up and down hill cultivation in regard to loss of carbon and nitrogen, 20 sets of samples were taken from farmers' fields in the eastern half of Kansas. Each site is represented by three samples, the first of which was located on sod land which, in so far as could be determined, had never been cultivated. The two additional samples were taken from an adjacent cultivated field of similar slope, one where the cultivation marks were directed up and down and the other where the cultivation has been approximately across the slope. These samples were mostly taken from fields of such dimension or location that past cultivation has been predominantly in one direction. Locations representing across the slope cultivation were selected only by observation and have very probably suffered greater erosion losses than would have been the case with carefully contour cultivated land.

With the exception of sites 18 and 20, which are located at the extreme eastern edge of the chernozem belt, all of the soils sampled belong to the Prairie group. In texture the soils are mostly silt loams or silty clay loams, but very fine sandy loams are found at sites 1, 2, 4, and 15. The exact period of cultivation could not be determined, but by statements obtained from farmers it was found that, with two or three exceptions, the cultural period was at least 30 years, and in many cases was much longer. Settlement in the eastern part of the state started about 1855 and in the central area was about 10 years later.

At each site a 0- to 7-inch surface sample and a 7- to 20-inch subsurface sample were taken. The samples were collected in cardboard cartons, brought to the laboratory, air dried, and stored until the following winter when the analyses were made. The samples from northeast and north central Kansas were taken in 1936, and those for southeast and south central Kansas in 1937.

Organic carbon and total nitrogen determinations were made on each sample. The organic carbon was determined by the method of Schollenberger as outlined by Allison (1).[3] For the nitrogen determination the samples were digested according to the Gunning-Hibbard procedure, distilled into 4% boric acid, and titrated with N/7 H_2SO_4 in the presence of brom-cresol-green and methyl red. The data obtained are presented in Tables 1 and 2 and are shown graphically in Fig. 1.

[1]Contribution No. 293 from the Agronomy Department of the Kansas Agricultural Experiment Station, Manhattan, Kan. Received for publication March 20, 1939.
[2]Assistant Professor of Soils and Associate Professor of Soils, respectively.
[3]Figures in parenthesis refer to "Literature Cited", p. 632.

Data covering samples from approximately one-half of the state and representing 13 soil series, 18 soil types, and different rainfall conditions would be expected to be highly variable. However, the variability does not conceal some very definite trends in the data.

LOSS OF CARBON AND NITROGEN DUE TO CULTIVATION

A comparison of the data in column 2 with that in column 4 of Tables 1 and 2 or an examination of Fig. 1 show a very evident decrease in carbon as a result of cultivation and cropping. Columns 3 and 5 show a similar reduction in nitrogen resulting from the same treatment. The average of the data for the 20 sites shows a loss of 37% of the carbon and 32% of the nitrogen from the surface soil, while the loss from the subsurface soil was, respectively, 25 and 20%. In 19 of the cases the carbon and nitrogen in both the surface and subsurface soil have decreased as a result of cultivation. The exception is probably due to sampling error. Statistical treatment shows this loss to be highly significant.

The nitrogen loss has been relatively less than the carbon loss. In 17 of the cases in both the surface and subsurface, the carbon-nitrogen ratio has decreased as a result of cultivation. This is in agreement with the frequent observation that as the decomposition of organic matter proceeds, the carbon-nitrogen ratio becomes narrower.

Under conditions at three experimental fields in western Kansas very large losses of nitrogen were found by Gainey, Sewell, and Latshaw (2) to result from cultivation and cropping. The amount of this loss was largely dependent on the amount of nitrogen originally present in the soil. When the data of Table 1 are divided into two groups according to nitrogen content, greater absolute loss from the higher nitrogen group is found, the nitrogen decreasing from an average of 0.217% to 0.145% while for the lower group the decrease was from an average of 0.152 to 0.104%. However, the percentage loss remains about constant, being 33.2 for the upper group and 31.3 for the lower group.

A "cultivation factor" was established by expressing the carbon in the sample cultivated across the slope as percentage of the carbon in the sod sample. This represents the relative amount of carbon which was retained following the cultural treatments in use on the farm when erosion was at least partially controlled. These data are given in column 8 of Tables 1 and 2, and show a very interesting relationship between the carbon loss and the amount of annual rainfall, the loss becoming greater as the rainfall decreases. This relationship is shown distinctly in Fig. 2 where the "cultivation factor" for the surface soil is plotted against the rainfall. The correlation coefficient for these data is .5737, giving odds for significance of slightly greater than 99 to 1. In the subsoil data the correlation coefficient is .2594, giving odds for significance of only about 7 to 1.

The data are not sufficiently extensive and do not cover a wide enough rainfall area to establish the exact nature of the curve. Yet, averages of the groups of samples shown in Fig. 2 fall close to a straight line. Sewell and Gainey (5) found that under cultivation a

TABLE I.—*Carbon, nitrogen, and related data for the surface soil.*

Sample No.	Sod C, %	Sod N, %	Across slope C, %	Across slope N, %	Up and down slope C, %	Up and down slope N, %	Cultivation factor,* %	Conservation factor,† %	Rainfall, inches	Slope	Country
Southeast Kansas											
1	1.21	0.094	0.93	0.077	0.79	0.068	76.9	84.9	40.12	3.7	Labette
2	1.96	0.142	1.13	0.092	0.77	0.066	57.7	68.1	40.12	2.5	Labette
3	3.16	0.226	3.02	0.222	2.51	0.186	95.6	83.1	38.08	1.5	Allen
4	2.34	0.172	1.34	0.100	1.29	0.104	57.3	96.3	37.71	2.3	Montgomery
5	2.24	0.170	2.39	0.181	1.94	0.160	106.7	81.2	36.41	3.5	Franklin
Av.	2.18	0.161	1.76	0.134	1.46	0.117	78.8	82.7	38.49	2.7	
Rel.‡	100	100	80.7	83.2	67.0	72.7	—	—	—	—	
Northeast Kansas											
6	2.36	0.185	1.57	0.119	1.39	0.117	66.5	88.5	36.34	8.0	Jackson
7	2.97	0.214	2.40	0.178	1.91	0.155	80.8	79.6	35.50	8.0	Leavenworth
8	2.91	0.222	2.15	0.165	1.54	0.127	73.9	71.6	35.50	8.0	Leavenworth
9	1.98	0.156	0.73	0.073	0.52	0.057	36.9	71.2	34.29	25.0	Doniphan
10	3.05	0.242	1.57	0.140	1.39	0.127	51.5	88.5	33.81	10.0	Doniphan
Av.	2.65	0.204	1.68	0.135	1.35	0.117	61.9	79.9	35.09	—	
Rel.	100	100	63.4	66.2	50.9	57.4	—	—	—	—	
South Central Kansas											
11	1.90	0.141	1.17	0.096	1.12	0.094	61.6	95.7	33.42	2.9	Cowley
12	2.19	0.153	1.42	0.119	1.06	0.091	64.8	74.6	33.42	2.1	Cowley
13	3.21	0.236	2.27	0.158	2.06	0.163	70.7	90.7	31.37	3.4	Marion
14	3.31	0.225	1.90	0.145	2.57	0.188	57.4	135.3	31.37	4.0	Marion
Av.	2.65	0.189	1.69	0.130	1.70	0.134	63.6	99.1	32.40	—	
Rel.	100	100	63.8	68.8	64.2	70.8	—	—	—	—	
North Central Kansas											
15	1.80	0.139	1.16	0.097	0.98	0.087	64.4	84.5	29.54	15.0	Washington
16	2.96	0.227	1.37	0.119	1.27	0.099	46.3	92.7	28.31	5.0	Clay
17	2.26	0.177	1.13	0.100	1.25	0.118	50.0	110.6	28.31	7.0	Clay
18	2.19	0.172	1.05	0.107	0.67	0.074	47.1	63.8	24.97	12.0	Jewell
19	2.73	0.209	0.96	0.097	0.94	0.093	35.2	97.9	24.97	7.0	Jewell
20	2.37	0.186	1.26	0.112	1.53	0.138	53.2	121.4	24.97	5.0	Jewell
Av.	2.39	0.185	1.16	0.105	1.11	0.102	49.4	95.2	26.84	—	
Rel.	100	100	48.5	56.8	46.4	55.1	—	—	—	—	
Average											
Av.	2.46	0.184	1.55	0.125	1.37	0.116	62.7	89.0	—	—	
Rel.	100	100	63.3	68.0	55.9	63.0	—	—	—	—	

*Carbon for the site cultivated across the slope expressed as a percentage of the carbon in the sod sample.
†Carbon for the site cultivated up and down the slope expressed as a percentage of the carbon in the sample cultivated across the slope.
‡Carbon or nitrogen expressed as percentage of the amount in the sod sample.

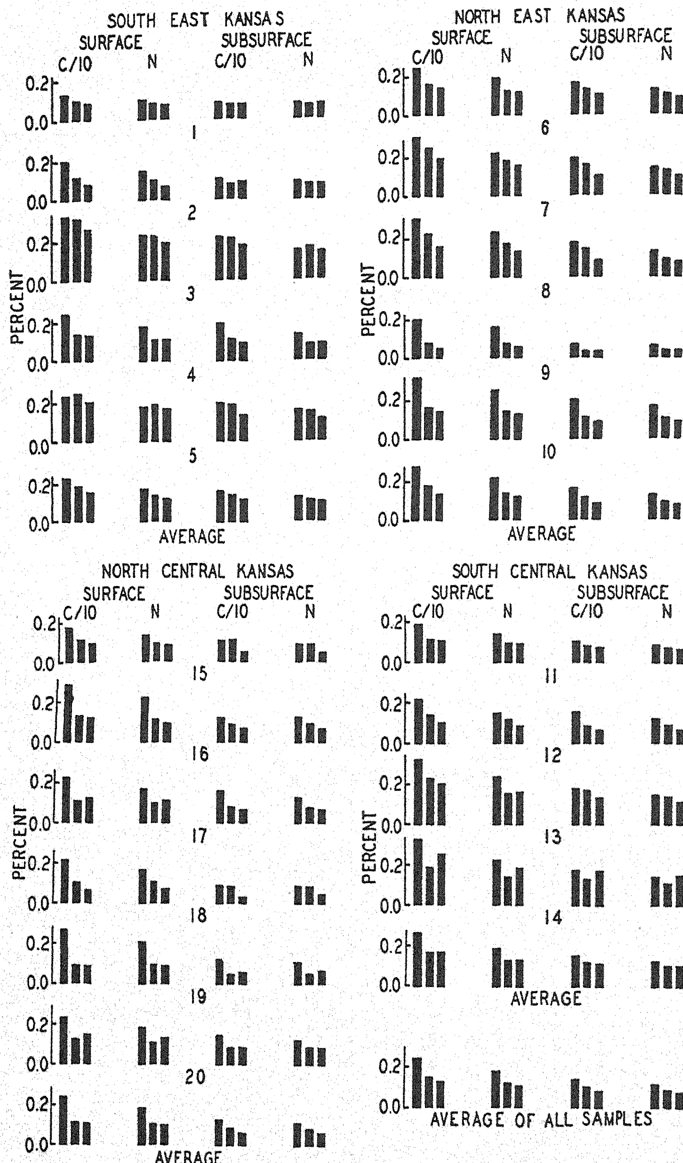

FIG. 1.—Carbon and nitrogen content of soil under sod and of similar soils differently cultivated. In each group of three, the left bar represents sod land, the center bar land cultivated across the slope, and the right bar land cultivated up and down the slope. For convenience in presentation the carbon data have been divided by 10.

soil at Colby where the annual rainfall is 18.4 inches lost 60% of its carbon in 23 years, a soil at Garden City under 20.2-inch rainfall lost 39.5% in 20 years, and one at Hays under rainfall of 23.7 inches lost 54.5% in 26 years. These soils also differ somewhat in texture, the Garden City soil being somewhat coarser than that at Colby or Hays. These losses are of about the same order as those obtained by the authors for samples taken in Jewell County under 25-inch rainfall. This may indicate a leveling of the line in that portion represented

TABLE 2.—*Carbon and nitrogen data for the subsurface soil.*

Sample No.	Sod		Across slope		Up and down slope		Cultivation factor,* %	Conservation factor,† %
	C, %	N, %	C, %	N, %	C, %	N, %		
				Southeast Kansas				
1	0.80	0.075	0.70	0.066	0.75	0.072	87.5	107.1
2	1.03	0.086	0.76	0.068	0.87	0.078	73.8	114.5
3	2.12	0.150	2.08	0.168	1.72	0.144	98.1	82.7
4	1.82	0.134	1.01	0.090	0.89	0.095	55.5	88.1
5	1.88	0.158	1.80	0.148	1.26	0.114	95.7	70.0
Av.	1.53	0.121	1.27	0.108	1.10	0.101	82.1	92.5
Rel.‡	100	100	83.0	89.0	71.9	83.5	—	—
				Northeast Kansas				
6	1.62	0.128	1.31	0.105	1.01	0.091	80.9	77.1
7	1.93	0.143	1.59	0.132	1.03	0.102	82.4	64.8
8	1.73	0.134	1.41	0.094	0.82	0.080	81.5	58.2
9	0.68	0.066	0.35	0.041	0.35	0.043	51.5	100.0
10	1.99	0.169	1.15	0.108	0.94	0.089	57.8	81.7
Av.	1.59	0.128	1.16	0.096	0.83	0.081	70.8	76.4
Rel.	100	100	73.0	75.0	52.2	63.3	—	—
				South Central Kansas				
11	1.07	0.091	0.86	0.077	0.79	0.069	80.4	91.9
12	1.60	0.123	0.92	0.094	0.71	0.068	57.5	77.2
13	1.81	0.152	1.77	0.142	1.39	0.117	97.8	78.5
14	1.79	0.143	1.33	0.112	1.73	0.154	74.3	130.1
Av.	1.57	0.127	1.22	0.106	1.16	0.102	77.5	94.4
Rel.	100	100	77.7	83.5	73.9	80.3	—	—
				North Central Kansas				
15	1.09	0.092	1.12	0.090	0.50	0.048	102.8	44.6
16	1.28	0.129	0.92	0.098	0.74	0.071	71.9	80.4
17	1.63	0.130	0.82	0.080	0.70	0.073	50.3	85.4
18	0.96	0.091	0.88	0.087	0.35	0.046	91.7	39.8
19	1.22	0.112	0.52	0.058	0.60	0.069	42.6	115.4
20	1.49	0.123	0.88	0.092	0.91	0.091	59.1	103.4
Av.	1.28	0.113	0.86	0.084	0.63	0.066	69.7	78.2
Rel.	100	100	67.2	74.3	49.2	58.4	—	—
				Average				
Av.	1.48	0.121	1.11	0.097	0.90	0.086	74.7	84.5
Rel.	100	100	75.0	80.1	60.8	71.1	—	—

*Carbon for the site cultivated across the slope expressed as a percentage of the carbon in the sod sample.
†Carbon for the site cultivated up and down the slope expressed as a percentage of the carbon in the sample cultivated across the slope.
‡Carbon or nitrogen expressed as percentage of the amount in the sod sample.

by the samples of the lower rainfall areas or it may be that the period of cultivation at these western Kansas sites has been somewhat shorter than in Jewell County and the loss of carbon has not proceeded as far.

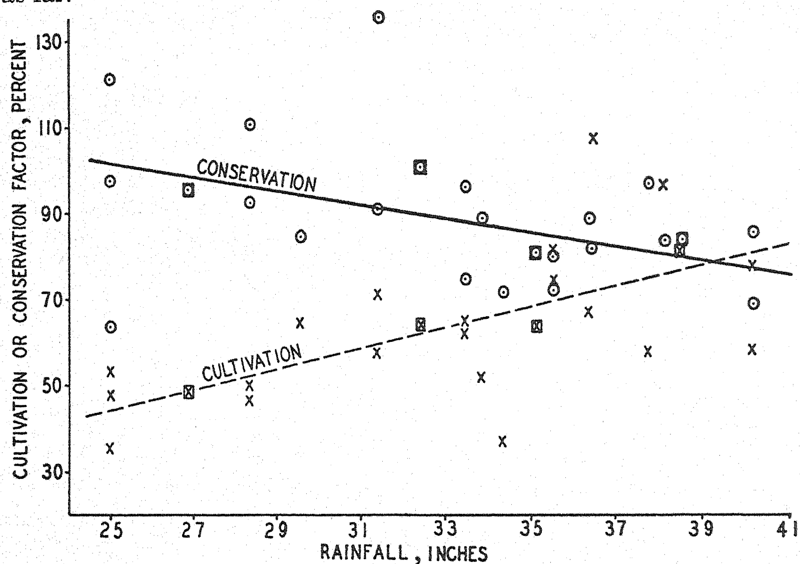

FIG. 2.—Cultivation and conservation factors in relation to rainfall. The x symbols represent "cultivation factors"; the circle and dot, "conservation factors"; and the boxed symbols group averages. The lines are drawn in from inspection of the data. (See footnotes to Table 1.)

The cultivation data at the upper end of the curve in Fig. 2 are quite variable, which may indicate that the apparent straight line relationship is starting to break down. However, support for the idea that a rise may continue with increasing rainfall is provided by Wheeting (6) who finds an increase in the carbon content of the humid forest soils of western Washington following cultivation and cropping. His data are not directly applicable to eastern Kansas conditions since it has been shown by Jenny (3) that organic matter relationships in the soil are dependent on at least temperature and moisture.

LOSS OF CARBON AND NITROGEN DUE TO EROSION

An examination of Tables 1 and 2 and of Fig. 1 shows that a greater loss of carbon and nitrogen has occurred from the sites where cultivation was directed up and down the slope than where it was across the slope. This loss is attributed entirely to erosion and, while it is not the total erosion loss, it is a loss that could readily have been prevented by proper cultural treatment. It should again be pointed out that the samples representing across the slope cultivation were selected only by observation and the data are consequently a very conservative approximation of the results that could be obtained with careful contour cultivation.

A comparison of the data in column 4 with those in column 6 of the tables shows that cultivation across the slope when compared with cultivation up and down the slope has maintained more carbon in the surface soil in 17 of the 20 cases and in the subsoil in 15 cases. The nitrogen loss due to erosion has been slightly less than the carbon loss. The average of all of the data for the surface soils shows that cultivation across the slope when compared with sod land has maintained 63.3% of the carbon while up and down the slope cultivation maintained only 55.9%. If the eastern Kansas data only are considered the percentages are, respectively, 71.1 and 57.8. For the 20 sites, cultivation across the slope conserved 16.8% of the carbon that was lost when cultivation was directed up and down the slope while in eastern Kansas it conserved 31.5%. A similar conservation can be observed from the subsoil data. Calculation of the Z value according to Love and Brunson (4) and use of Love's tables show odds of 65 to 1 for significance of the carbon loss due to erosion from the surface soil, while in the subsoil the odds for significance are 430 to 1.

A "conservation factor" was established by expressing the carbon in the samples taken where the cultivation had been directed up and down the slope as a percentage of that in the samples from land which had been cultivated across the slope. According to this concept, when the carbon content equals that of the sample taken where cultivation was across the slope, conservation is considered to be 100%. These data are given in column 9 of Tables 1 and 2. From the group averages it is apparent that the erosion loss has been greater from the two eastern sections of the state than from the two central sections. The data for the central sections are highly variable and though the averages show practically no saving for contour cultivation, this is very probably a result of the data being insufficient for areas in which variability is so high. The average for south central Kansas should be questioned since three of the values are of the same order and show an average "conservation factor" of 87 which is offset by the data at site 14 where the two cultivated samples were taken at a considerable distance apart.

In Fig. 2 the "conservation factor" for the surface soil is plotted against rainfall and indicates a possible inverse relationship, the percentage of carbon conserved increasing as the rainfall decreases. These data, however, yield a correlation coefficient of only —.4003 giving odds of slightly less than 19 to 1 while the subsoil data give a coefficient of +.1235.

Throughout the area studied, the rainfall comes mostly during the growing season and much of it in the form of downpours.

SUMMARY

At each of 20 sites in the eastern half of Kansas soil samples were taken to represent sod land, land which has been cultivated across the slope, and land which has been cultivated up and down the slope. Organic carbon and total nitrogen determinations were made on these samples.

In comparison with the sod sample, cultivation across the slope associated with cropping has brought about a highly significant loss

of carbon and nitrogen amounting to 37 and 32%, respectively, for the surface 7 inches of soil, and 25 and 20% in the 7- to 20-inch layer. The actual loss of carbon becomes significantly greater as the average annual rainfall decreases from 40 inches in southeast Kansas to 25 inches in north central Kansas.

The carbon loss which occurred from the surface soil where the land has been cultivated across the slope is 16.8% less than where cultivation has been up and down the slope. This saving is statistically significant. If only that half of the data from the relatively humid extreme eastern section of the state is considered, the carbon loss was reduced 31.5% by cultivation across the slope.

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BURIED RED RICE SEED[1]

W. L. GOSS AND EDGAR BROWN[2]

RED rice is the most troublesome weed pest occurring in rice fields. Once harvested with the cultivated rice crop, it cannot be removed by any known machinery. The kernel is often slightly smaller than that of commercial rice varieties and the red seed coat from which it derives its name cannot be entirely removed in the milling process without materially reducing the yield of head rice. Streaks of the red bran which often are left on the milled kernels seriously injure the appearance of the milled rice and lower the grade.

A survey of seed rice used in the states of Louisiana, Texas, and Arkansas was made in the spring of 1929 by W. D. Smith, J. J. Deffes, and C. H. Bennett of the Rice Project, Grain Investigations, Grain Division, Bureau of Agricultural Economics, U. S. Dept. of Agriculture. They drew samples from 337 lots of rice seed actually being planted. Of these samples, 54% contained seeds of red rice, the average number per pound being 28. One sample showed 585 red rice per pound. Using 80 pounds per acre, over half of the rice growers were planting on an average about 2,300 red rice seeds per acre or 1 on every 18 square feet.

A similar survey was made in California by the Federal-State Seed Laboratory in the spring of 1932. Samples were obtained from the seed being used in planting approximately one-sixth of the state's rice acreage. Of the samples taken, 42% contained red rice seed ranging from 3 to 57 seeds per pound. The California Federal-State rice inspection service reported in 1932 that of 907,251 sacks of rough rice inspected, 2.9% graded No. 2, 1.9% graded No. 3, 3.2% graded No. 4, and 0.3% graded No. 5 because of red rice.

Red rice is known to volunteer in the rice fields of the South, but just how long the seeds are capable of remaining viable in the soil is not definitely known.

An experiment was planned by the U. S. Dept. of Agriculture to determine the length of time red rice seed will remain viable in the soil under different climatic conditions and was started in the fall of 1930.

PLAN OF EXPERIMENT

Five samples of red and two samples of cultivated white rice were buried on the rice experiment stations at Stuttgart, Ark., October 28, 1930, at Beaumont, Tex., October 31, 1930, and at Biggs, Calif., November 17, 1930. At each station, 12 pits were dug, 6 so located that they would be submerged as is practiced in growing a normal crop of rice, and 6 so located that they would receive natural rainfall only.

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[1]Contribution from the U. S. Dept. of Agriculture, Washington, D. C., in cooperation with the State Department of Agriculture, Sacramento, Calif. Received for publication March 20, 1939.

[2]Senior Botanist, Enforcement of Federal Seed Act, U. S. Dept. of Agriculture, and the State Department of Agriculture, Sacramento, Calif., and Principal Botanist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, respectively.

The seed was buried as follows: 200 seeds were mixed with enough dry soil to fill a 4-inch flower pot about three-quarters full. The mixture of the seed and soil was then pressed firmly into the pots and the remaining space filled with dry soil and then covered with a porous clay saucer. The pot and saucer were then inverted and placed in the pit, which was dug deep enough to allow for a 4-inch soil cover. The soil was packed firmly about the pots. The porous nature of the pots allows free circulation of moisture through the soil in the pots. The object was to subject the seeds, as nearly as possible, to the conditions which would prevail if they were plowed under and to be able to reclaim them for periodic germination tests. Seven pots, each containing a different sample of seed, were placed in each pit. It was planned to take up the seven pots from one of the dry and one of the wet pits at each of the three stations and test the seeds for germination in 1931, 1932, 1933, 1935, 1937, and 1940.

At Biggs, envelopes containing seed from each lot were placed in quart glass easy-seal jars, sealed as in canning fruit, and buried bottom-side up in each pit of the dry plot. In the irrigated plot at Biggs there was buried in each pit an unmarked pot containing seeds of water plantain (*Alisma plantago*) and water grass (*Echinochloa crusgalli*). Both the water plantain and the water grass have produced some sprouts each year that they have been tested previous to 1937, but the percentage of growth has been low, perhaps due to unfavorable conditions for germination. Weed seeds are often difficult to germinate under laboratory conditions.

Sets from the irrigated and non-irrigated plots were taken up and tested for germination in the spring of 1931, 1932, 1933, 1935, and 1937.

RESULTS

Table 1 shows the germination results obtained from the seeds buried in actual contact with the soil at the three stations for each of the years in which they have been taken up and tested for germination.

From these results, it is evident that the southern red rices retain their vitality when buried in the soil much longer than does either the Italian or California red or the cultivated white rices. It also appears that the southern reds retain their viability longer under Texas and Arkansas conditions than under California conditions. Under Texas and Arkansas conditions, the seed buried in the irrigated plots retained its vitality longer than that in the unirrigated plots. In California, the results were practically the same for the irrigated and unirrigated plots except that the Italian purple-awned red survived much longer under dry conditions. The California white-awned red rice and the two samples of cultivated white rice gave little or no germination after the first year. The Italian purple-awned red rice from California showed more resistance and retained its viability longer in California than in either Texas or Arkansas.

Table 2 gives the germination of each lot of seed before it was buried, the germination of samples from the same lot kept in dry storage in the Seed Laboratory at Washington, D. C., and the germination of samples from the same lots after they had been buried in sealed containers protected from outside moisture but subjected to the same temperature conditions as the seed buried in the terra cotta

TABLE 1.—*Vitality of red rice seed after being buried in the ground for one, two, three, and five winters.**

Year	Beaumont, Tex.		Stuttgart, Ark.		Biggs, Cal.	
	Irrigated %	Non-irrigated %	Irrigated %	Non-irrigated %	Irrigated %	Non-irrigated %
Italian Red Rice, Purple Awns						
1931	0.0	1.0	29.0	0.0	2.0	15.5†
1932	1.5	2.0	14.0	0.5	0.5	35.0
1933	0.5	0.0	1.5	1.5	0.5	16.5
1935	0.0	0.0	2.5	1.0	0.05	0.0
1937	0.0	0.0	0.0	0.5	0.0	0.0
California Red Rice, White Awns						
1931	0.0	0.0	17.0	0.0	4.5	2.0
1932	0.0	0.0	4.5	2.0	1.0	0.0
1933	0.0	0.0	7.0	0.5	1.0	0.0
1935	0.0	0.0	0.0	0.0	0.0	0.0
1937	0.0	0.0	3.0	0.0	0.0	0.0
Southern Blackhull Red Rice						
1931	80.0†	47.5†	87.0	36.0†	95.0	99.0
1932	88.5	82.0	80.0	50.5	82.0	66.0
1933	80.5	59.0	47.5	31.0	7.0	1.0
1935	59.5	2.0	27.0	27.5	3.0	0.0
1937	2.5	0.0	20.0	1.5	0.0	0.0
Southern Red Rice						
1931	58.0†	67.5	75.0	18.0†	67.5	63.5
1932	64.5	17.0†	45.0	42.5	67.0	36.5
1933	50.5	25.0	56.5	35.0	19.0	3.0
1935	7.0	0.0	11.5	0.5	6.0	0.0
1937	0.0	0.0	4.5	1.5	0.0	0.0
Southern Red Rice						
1931	54.5	70.5	67.5†	20.0†	67.5	58.0
1932	44.0	8.5†	79.5	51.5	65.0	18.0
1933	15.5	23.0	59.0	27.5	5.5	5.0
1935	0.0	0.0	12.0	7.0	6.0	0.0
1937	0.0	0.5	2.5	1.0	0.5	0.0
Supreme Blue Rose Rice						
1931	2.0	0.0	23.5	0.0	0.5	6.0
1932	0.0	0.0	0.0	0.0	0.0	0.0
1933	0.0	0.0	0.0	0.0	0.0	0.0
1935	0.0	0.0	0.0	0.0	0.0	0.0
1937	0.0	0.0	0.0	0.0	0.0	0.0
Caloro Rice						
1931	1.0	0.5	18.0	0.0	9.0	8.5
1932	0.0	0.0	0.0	0.0	1.0	0.0
1933	0.0	0.0	0.0	0.0	0.0	0.0
1935	0.0	0.0	0.0	0.0	0.0	0.0
1937	0.0	0.0	0.0	0.0	0.0	0.0

*The germination tests of the seed buried at Biggs, Cal., were made at the California Cooperative Seed Testing Laboratory, Sacramento, Cal., and the tests of those buried at Beaumont, Tex., and Stuttgart, Ark., were made at the Division of Seed Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture, Washington, D. C.

†These apparent low percentages were due to germination having occurred before the seed reached Washington, D. C., and the percentage could not be determined. The percentages show only germination after receipt.

pots. No test was made of the laboratory stored seed after 1933. The seed buried in the glass jar at Biggs retained its vitality perfectly for 2 years and only the two samples of cultivated rice showed serious loss of germination the third year. The rubber seal on the

TABLE 2.—*Germination of original red rice seed and of seed in dry storage in the laboratory and in sealed containers buried in the field.*

Year tested	Germination		
	At time of storage, %	Laboratory storage at Washington, D. C., %	Sealed container, non-irrigated plot, Biggs, Calif., %
	Italian Red Rice, Purple Awns		
1930	97.0		
1931		98.50	97.00
1932		99.00	96.50
1933		90.00	95.50
	California Red Rice, White Awns		
1930	93.00		
1931		97.50	97.00
1932		92.00	97.50
1933		85.50	83.50
	Southern Red Rice, Blackhull		
1930	76.00*		
1931		97.00	92.00
1932		97.50	100.00
1933		93.00	85.00
	Southern Red Rice		
1930	82.00*		
1931		94.00	88.00
1932		88.00	90.00
1933		82.50	84.50
	Southern Red Rice		
1930	83.00*		
1931		90.50	86.00
1932		86.00	88.50
1933		85.00	88.50
	Supreme Blue Rose Rice		
1930	86.50		
1931		92.50	94.00
1932		83.50	85.00
1933		74.50	62.50
	Caloro Rice		
1930	93.50		
1931		94.00	94.00
1932		81.50	88.50
1933		45.00	10.50

*Apparently seed was dormant when original test was made.

glass jar failed before the seeds were taken up in 1935, admitting moisture and consequently spoiling the seed, making a germination test useless.

CONCLUSIONS

Under dry storage at soil temperature conditions existing in California, all of the red rices tested showed good vitality after three winters. The cultivated rices showed loss of vitality in the third year, especially the Caloro variety.

Cultivated white rice when buried in the soil at the depth of ordinary plowing loses its vitality during the first winter.

Italian and California red rices behave very similarly to cultivated rices although they are slightly more persistent.

In general, the seed remained alive longer in the irrigated than in the non-irrigated plots.

The Italian purple-awned red variety retains its vitality longer than the California white-awned, particularly under dry conditions.

The southern red rices show good vitality after 3 years in the soil and some germination after 7 years. They appear to persist longer under Texas and Arkansas conditions than under California conditions.

It is evident that clean culture during a short rotation will not rid the land of red rice.

THE EFFECT OF CARBON DIOXIDE PRESSURE UPON EQUILIBRIUM OF THE SYSTEM HYDROGEN COLLOIDAL CLAY-H_2O-$CaCO_3$[1]

CHARLES F. SIMMONS[2]

THE reaction between $CaCO_3$ and soils is one of the most important in soil chemistry. As a result it has been investigated under a wide range of conditions by a very large number of workers. In the great majority of these studies, however, factors known to have an appreciable effect upon the reaction were not adequately controlled. The pressure of CO_2 above the reacting system is one of the most important of these factors. The carbon dioxide content of the soil air is known to vary from 0.03 to 12.0% largely as a result of variations in biological activity and soil ventilation. It is well known that CO_2 dissolves in water to form carbonic acid. The effect of the pressure of CO_2 upon the amount absorbed by water and various salt solutions has been thoroughly investigated. The data of Bohr (3)[3] are commonly regarded as quite reliable. Water charged with CO_2 is known to be a good solvent for many soil minerals, especially calcite. The effect of CO_2 pressure upon the solubility of calcite in water has been investigated (8) and later reinvestigated by Johnston and his students. Frear and Johnston (5) give values obtained by plotting the best existing data.

It has been commonly assumed (4) that the amount of $Ca(HCO_3)_2$ in solution in a soil suspension containing an excess of soil $CaCO_3$ is the same as it would be if the soil were not present. If this is true and the amount of water present and the pressure of CO_2 is known, it should be possible to calculate the amount of Ca present as $Ca(HCO_3)_2$ and the amount of dissolved CO_2 in soil-$CaCO_3$-H_2O systems from the data of Frear and Johnston (5) and Bohr (3), respectively. Some of the data obtained in the course of this investigation tend to throw doubt on the strict validity of the above assumption, but a discussion of this point will be reserved until later.

Jensen (7) studied the amount of Ca fixed by soils from $CaCO_3$ at the pressure of CO_2 existing in the atmosphere by means of serial experiments in which a series of soil samples was treated with regular increments of $Ca(OH)_2$. They were then aerated until equilibrium with the air was obtained. Constancy of the pH value as measured with the quinhydrone electrode was used as the criterion for reaching equilibrium. Buffer curves obtained by plotting the pH values thus obtained against the increments of $Ca(OH)_2$ added were used to characterize the acidity of various soils.

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[1]Contribution from the Department of Agronomy, Ohio Agricultural Experiment Station, Wooster, Ohio. Also presented as Research Paper, No. 640 Journal Series, University of Arkansas. Abstract of a dissertation presented to the Graduate School, Ohio State University, in partial fulfillment of the requirements for the degree of doctor of philosophy. Received for publication March 29, 1939.

[2]Extension Agronomist, University of Arkansas College of Agriculture. Formerly Assistant in Agronomy, Ohio Agricultural Experiment Station. Acknowledgment is made to Dr. Richard Bradfield under whose direction this study was made.

[3]Reference by numbers in parenthesis is to "Literature Cited", p. 648.

Bradfield and Allison (4), in an effort to find a more exact way of characterizing a soil "saturated with bases", studied various soil-$CaCO_3$-H_2O systems at the pressure of CO_2 of the atmosphere. The amount of Ca reacting with the soil was determined by analyzing the equilibrated samples for total CO_2, care being taken not to oxidize any of the organic matter of the soil. Since the total amount of $Ca(OH)_2$ added and the solubility of $Ca(HCO_3)_2$ and CO_2 were known, the amount of Ca fixed by the clay could be readily calculated. The amount fixed was found to be independent of the amount of $Ca(OH)_2$ added provided a sufficient excess was present to give some solid $CaCO_3$ after equilibration. This fact is a strong argument in favor of this concept of a base-saturated soil. The practical utility of this concept would be influenced by the sensitivity of the equilibrium to such changes in CO_2 pressure as are known to occur naturally in the soil.

Practically all the cations fixed by clay in the range of pH values involved in this study (6.5 to 8.5) are held in exchangeable form. The laws which have been found to apply to the cation exchange reactions of clays and permutits by Wiegner (11) and his students, especially Jenny (6), would be expected to apply here. These studies show that the amount of a cation absorbed by the clay depends upon: (a) The specific absorbability of the ion, which, in turn, depends upon its valance and ionic radius, and (b) the concentration of the cation at which equilibrium has been established. The empirical Freundlich adsorption isotherm applies with fair accuracy to these systems. Adsorption isotherms show that the H ion is much more strongly adsorbed by clays than is the Ca ion at similar concentrations.

In the present study H^+ and Ca^{++} are the only cations involved. They may be considered as competing with each other for a place on the clay particles. The excess of solid $CaCO_3$ always present in these experiments furnishes an inexhaustible reserve of Ca ions. The increasing quantities of CO_2 dissolving at the higher CO_2 pressures tend to increase the concentration of the H ions. The concentration of both Ca^{++} and H^+ ions will increase then as the CO_2 pressure is increased. The increases in the concentration of both ions to be expected from the investigations of Frear and Johnston (5) on the system $CaCO_3$-H_2O-CO_2 are shown in Figs. 1 and 2. It is obvious from these graphs that at the higher CO_2 pressure the H-ion concentration will increase more rapidly relatively than will the Ca-ion concentration. This fact when coupled with the known greater specific absorbability of the H ion would lead us to expect that the amount of Ca fixed by the clay would decrease as the CO_2 pressure is increased. The available data, however, are insufficient to enable one to calculate the magnitude of the decrease in any specific case.

The object of the present investigation is to determine the amount of Ca fixed by a hydrogen colloidal clay when it is treated with a known excess of $CaCO_3$ and then brought into equilibrium with various controlled pressures of CO_2, temperature being kept constant to within 0.1°C.

Expansion of this study to include some of the common soils is very desirable, but must be delayed until a complete study is made of the pure clay system. Individual studies of the bases found in the soil as well as the probable influence of the soil acids should be made.

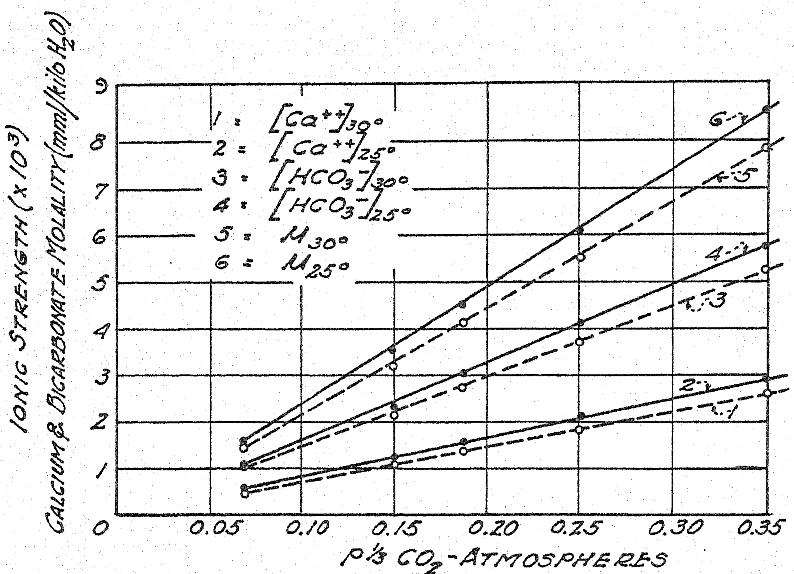

FIG. 1.—Effect of CO_2 pressure on the solubility of calcite in water.

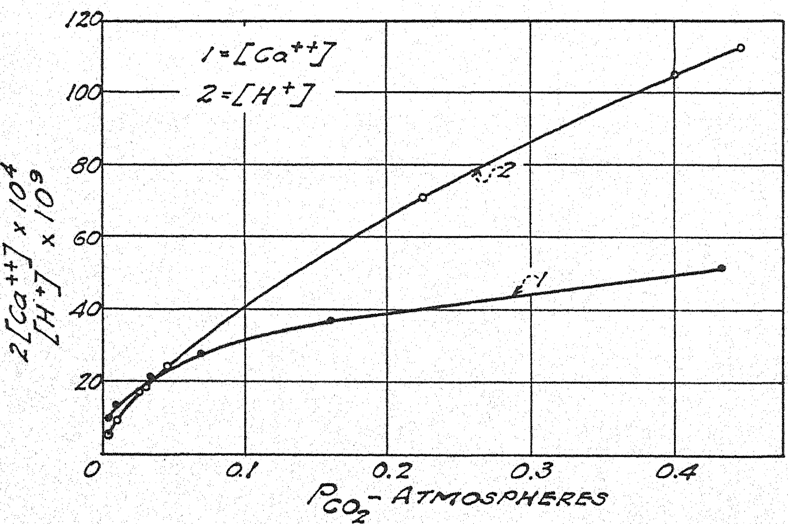

FIG. 2.—Effect of CO_2 pressure on Ca- and H-ion concentrations in aqueous solutions of calcite.

EXPERIMENTAL

PREPARATION OF MATERIALS

The colloidal clay used in this study was prepared from a Miami clay subsoil. It was dispersed with Na_2CO_3, centrifuged, and flocculated with HCl. After concentrating by centrifuging, the clay was electro-dialyzed to remove bases and

acids. Before being used it was oven dried at 105° C and then ground in an agate mortar. Because of the extreme difficulty of redispersing the colloidal clay after it had been dried, it is believed that the organic solvent method used by Truog and his students (10) would have been of considerable aid in this study.

The $Ca(OH)_2$ solution was prepared by the usual method from Merck's Blue Label CaO. The CaO was prepared by calcining C.P. $CaCO_3$ at 1050° C. The CO_2 used was a commercial grade, analyzing more than 99.9 per cent pure.

TIME REQUIRED TO REACH EQUILIBRIUM IN THE $CaCO_3$ SYSTEMS

CO_2 at 71.43 cm pressure was bubbled through 75 cc of 0.0361 N $Ca(OH)_2$ at 28.5° C to learn something of the time required for equilibrium in this system. The work of Bohr (3) shows that from 4 to 6 hours were necessary for equilibrium between CO_2 and H_2O under the conditions of his study, while Johnston and his students (5) found that several days were required for equilibrium between calcite, H_2O, and CO_2. Fig. 3 shows the change in conductivity of the $Ca(OH)_2$ solution as CO_2 was bubbled through. During the first minute the solution became turbid with the formation of $CaCO_3$ and the conductivity dropped. During the next few minutes the turbidity disappeared, the Ca being further carbonated to $Ca(HCO_3)_2$, and the conductivity increased sharply. After about 4 hours the excess $CaCO_3$ started precipitating on the walls of the vessel and the conductivity dropped slightly until after 10 to 12 hours it became constant. Since the work of Bradfield and Allison (4) showed that equilibrium between the clay, $CaCO_3$, H_2O, and CO_2 of the air was reached within 4 or 5 hours after carbonating, it is

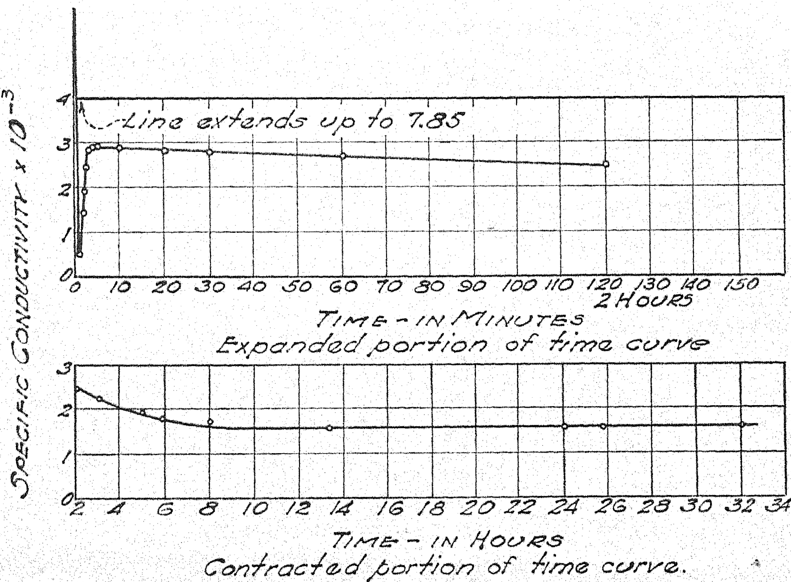

FIG. 3.—Time of equilibrium between CO_2 and $Ca(OH)_2$. Conductimetric study.

believed that in these proposed studies equilibrium would be reached between 4 and 12 hours, depending on the CO_2 pressure used.

To be sure that equilibrium was established in the clay-$CaCO_3$-H_2O-CO_2 systems, pH determinations were made after the gas mixture had been bubbled through for 15 hours. Three determinations were made on each flask over a period of 3 hours. No change in pH was observed; equilibrium had apparently been established.

A third criterion of equilibrium was obtained by studying the rate of absorption of CO_2 by CaO, H_2O, and H-clay, using a gasometric technic. The materials were introduced into a flask which was then evacuated and attached to a gas system containing a gas buret and a manometer. Adjustment of gas pressure in the system was made then it was allowed to react with the mixture in the flask. After equilibrium was established at one CO_2 pressure, a higher pressure was introduced. The rates of reaction of the CO_2 with the mixture as a function of time are presented graphically in Fig. 4 and indicate

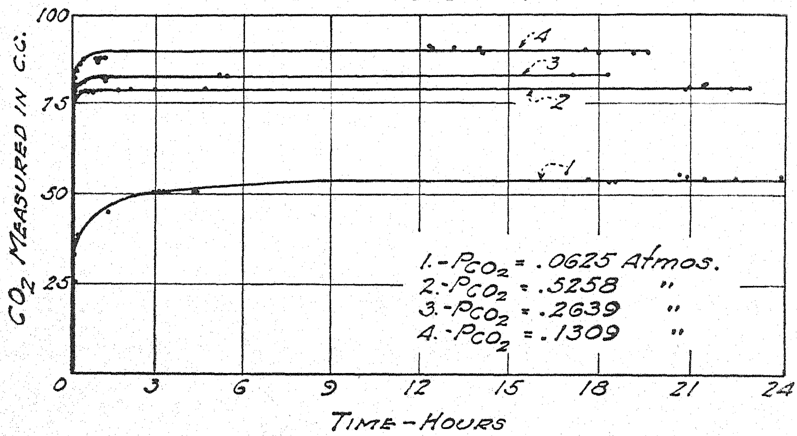

FIG. 4.—Time of equilibrium between CO_2 and a CaO-Clay-H_2O system. Gasometric study.

that equilibrium in all cases was established within 15 hours. These curves are shown only for the purpose of indicating rate of reaction.

Two general methods, static and dynamic, were used for this study, each having advantages and disadvantages peculiar to the method.

The gasometric system illustrated in Fig. 5 was used in the static method of study. The materials on which a study was made were put into the flask D, the total volume of which was about 75 cc. Since the flask was shaken vigorously (by a device not shown) during the reaction, it was necessary to have a suspension dilute enough to be agitated easily, but of small enough volume to stay in the bulb part when shaken. About 2 grams of clay and 30 cc of water were used. This proportion seems to have been about right.

The technic in this study consisted in introducing the dry clay and some rough glass beads into the flask, then adding CO_2-free H_2O and the freshly calcined CaO from a weighing vial, evacuating to remove air, closing the flask, and finally attaching it to the system.

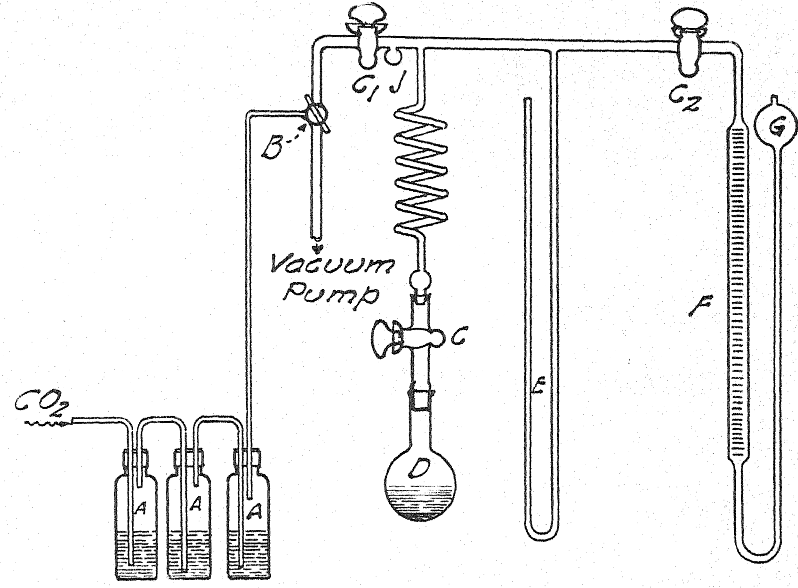

FIG. 5.—Apparatus for static study.

By means of the stop cocks shown, any part of the system could be evacuated by the pump. The enlargement J contained a very small quantity of water for keeping the system filled with H_2O vapor. With the flask still closed to the rest of the system, CO_2 was introduced through the flasks marked A containing a $CaCO_3$-H_2O mixture. This CO_2 was brought to equilibrium at a pressure indicated by the manometer E. The flask was then opened to the system and the CO_2 allowed to react with the materials studied. The quantity of CO_2 absorbed was measured by the gas buret F. After equilibrium was established at one pressure, the flask was closed and the procedure repeated for a higher pressure.

With such a method of study, very little analytical work is required and the rate of reaction can be easily observed. As indicated above when equilibrium is established at one pressure, another pressure can be studied by doing nothing more than changing the pressure and making the required observations and calculations.

Temperature control within narrow limits is necessary over a relatively large system when this method is used, partially because of the temperature effect on reaction, but chiefly because of sharp changes in the vapor pressure of H_2O at the temperatures used. This method was discontinued after several fairly satisfactory runs were made, because facilities for temperature control were not available. For measuring pressures of CO_2 comparable to those commonly found in soils, another type of manometer would be necessary. Since this system is subjected to rigorous strains for several days at reduced pressures, leaks can be very serious. Another possibility of error could be partial carbonation of the CaO in mixing the materials.

Despite these difficulties it is believed that this method would prove very satisfactory for studying this problem.

The dynamic method differed from that proposed by Bradfield and Allison only in the composition of the gas used. With this method very low CO_2 pressures can be used, pH studies can be made with ease, and a number of replications can be set up. $CaCO_3$ or $Ca(OH)_2$ may be used as the source of Ca, but since the time of reaction is so great where $CaCO_3$ is used, either $Ca(OH)_2$ or CaO would be preferable. The greatest disadvantages of this method are the difficulties in maintaining gas mixtures of constant composition, the time-consuming analytical work, and the fact that a sample of clay can be used only at one CO_2 pressure.

Fig. 6 illustrates one type of apparatus used in this study. The flowmeters C and D, the mercury escape valves A and B, and the mixing chamber E were used for giving a constant mixture of CO_2

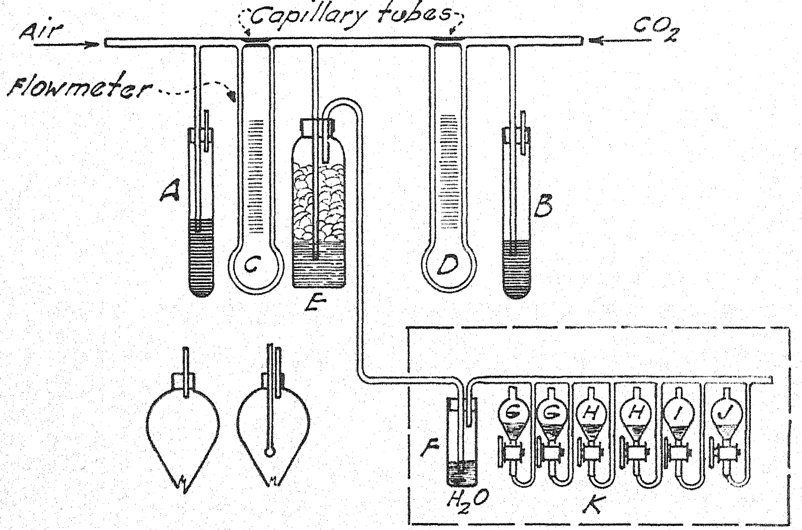

FIG. 6.—Apparatus for dynamic study.

and air which pass through F, containing water at the temperature of the water bath K. Flasks G, H, I, and J are ordinary 120-cc separatory funnels with the delivery tubes turned up for connecting to the gas line. Flasks G contained the clay-$Ca(OH)_2$ mixture, while flasks H contained an equal amount of $Ca(OH)_2$ but no clay and served as blanks. Flask I contained a small amount of $Ca(OH)_2$ for pH studies, while flask J contained NaOH for pH determinations from which the CO_2 content of the gas mixtures were calculated according to the method of Wilson and associates (12).

The clay-$Ca(OH)_2$ system was treated as follows: Approximately 2 grams of the dry clay and 75 cc of $Ca(OH)_2$ of known normality were introduced with several glass beads into the reaction flasks, which were then closed by means of rubber stoppers and weighed.

Air was bubbled through for 2 hours in order to mix the materials completely. The glass beads broke up the clay particles during this treatment, after which the system was carbonated with pure CO_2 for 5 minutes followed by an overnight bubbling with the desired CO_2-air mixture. After about 12 hours pH determinations were made on the system by means of a glass electrode and a Leeds and Northrup type K potentiometer using a Lindeman quadrant electrometer as a null-point instrument. Accuracy greater than 1 mv. was not attempted. The temperature of the reaction bath was 30° C±.1°. Three pH determinations were made over a period of 3 hours and when no change was observed equilibrium was considered to have been reached. A small amount of $Ca(OH)_2$ in flask I received the treatment above. After equilibrium had been established in the systems, the flasks G and H were closed, reweighed, and analyzed for total CO_2 according to the method of Schollenberger (9). Just before the analysis was made, enough CO_2-free water to fill the flask was introduced from the bottom. This eliminated the necessity of including the CO_2 above the equilibrated suspension in the analysis. The water was very carefully introduced, requiring about 1 minute, and seems to have done nothing more than effect a displacement of the gas, though it is possible that some small quantity of CO_2 in solution was lost.

The data obtained by these studies are summarized in Table 1 and Fig. 7. The amount of Ca absorbed by the clay was obtained by subtracting the amount of CO_2 observed from the total calculated amount based on CO_2 absorption in water and the solubility of

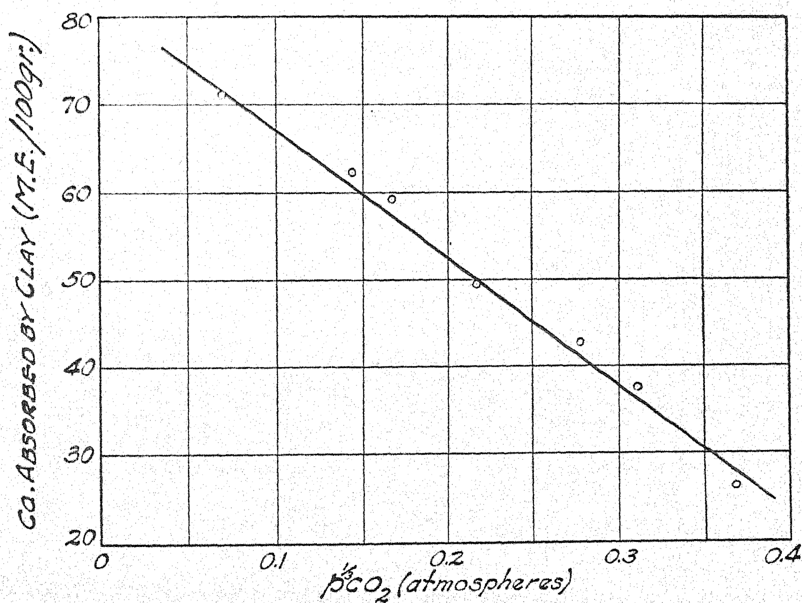

FIG. 7.—Effect of CO_2 pressure on calcium absorbed by colloidal clay as determined by dynamic study.

$Ca(HCO_3)_2$, with the assumptions already mentioned that the $Ca(HCO_3)_2$ solubility would not be affected by the clay. Since, however, the pH of the clay system was invariably higher than the pure carbonate system, a second calculation might be made of the bicarbonate solubility from pH values of the clay system using the mass action equations, or modifications of them, as follows:

$$\frac{[H^+][HCO_3^-]}{[H_2CO_3]} = K_1 \qquad 1$$

$$H_2CO_3 = \frac{\alpha P_{CO_2}}{22.267} \qquad 2$$

$$\text{and } [HCO_3^-] = \frac{K_1 \times \alpha \times P_{CO_2}}{[H^+] \times 22.267} \qquad 3$$

Such a treatment of the data is not justified until further study is made of this system.

In Table 1 are shown the values obtained by this study. From these data it is seen that the pH values observed in the clay systems were consistently higher than that of the pure $CaCO_3$ system at the same CO_2 pressure. It is probable that the actual differences between the pH values of the two systems are partially obscured by the experimental error in determining the values and that the actual differences would be some definite function of the CO_2 pressure. There is shown a very close agreement between the observed and calculated pH values of the pure $CaCO_3$ systems, differences in all cases being reasonably within the limits of experimental error of the glass electrode apparatus. A study of these pH values, possible through this method of study, would furnish much needed information about clay-$CaCO_3$-CO_2-H_2O systems that would explain many controversial questions.

TABLE 1.—*The effect of CO_2 pressure on pH and bicarbonate solubility in Clay-$CaCO_3$-H_2O and $CaCO_3$-H_2O systems.*

CO_2 pressure (atmospheres)	($P^{\frac{1}{3}}_{CO_2}$) (atmospheres)	pH clay system	pH clay system minus pH $CaCO_3$ system	Observed pH $CaCO_3$ system	Calculated pH $CaCO_3$ system*	Calculated pH minus observed pH $CaCO_3$ system	HCO_3 molality mml/kilo H_2O†	M.E. Ca absorbed per 100 grams clay
1	2	3	4	5	6	7	8	9
0.00033	0.069	8.57	0.15	8.42	8.37	−0.05	0.97	71.3
0.00295	0.144	7.97	0.31	7.66	7.76	0.10	2.15	62.4
0.00467	0.167	7.87	0.33	7.54	7.61	0.07	2.42	59.2
0.00999	0.215	7.67	0.35	7.32	7.38	0.06	3.10	49.7
0.02130	0.277	7.57	0.36	7.21	7.16	−0.05	4.05	43.0
0.03010	0.311	7.28	0.21	7.07	7.06	−0.01	4.52	37.9
0.05000	0.368	7.19	0.28	6.91	6.92	0.01	5.42	26.4

$^*pH = pK_1 - .5\sqrt{\mu} + \log\ [HCO_3^-] - \log\ [H_2CO_3]$.
†From Fig. 1.

The quantity of calcium absorbed by the clay is plotted as a function of the cube root of the CO_2 pressure in Fig. 7, and is shown to be indirectly proportional to the pressure so expressed. The decrease in calcium absorption as the CO_2 pressure is increased could be predicted from a study of Fig. 2 which shows that the relative H-ion concentration increases much more rapidly than does the Ca-ion concentration as the CO_2 pressure is increased within the ranges studied.

The data presented are an average of three determinations at most of the designated pressures. Many early studies were so inconsistent as to seem almost valueless at the time. Later studies indicated that equilibrium was probably never reached in some of these earlier studies. Constant pressure of gas was difficult to maintain. Prepared gas mixtures at definite CO_2 pressures would eliminate this possibility of error. The chief cause of inconsistencies was found to be due to the almost irreversible drying of the colloidal clay. In some of the studies it was found that equilibrium was not reached even though the gas mixture was bubbled through for 48 to 60 hours, while in other cases and at the same pressure, equilibrium was apparently reached within 10 to 12 hours. It was found that the glass beads were not doing a complete job of breaking down the clay particles in those flasks which apparently did not reach equilibrium. Just as soon as the beads were violently agitated, which completely broke down the aggregates, equilibrium could be quickly established. This breaking down of the aggregates was often accomplished by passing through air or carbon dioxide at a rapid rate before the gas mixture was used. Difficulties with the almost irreversible drying of colloidal clay were also experienced by Baver and Scarseth (1) who reported an exchange capacity of 30 M.E. for dried Lufkin colloidal clay after it had been dried as compared with 82 M.E. (2) for the completely hydrated colloid.

SUMMARY AND CONCLUSIONS

In this study some of the problems in the reaction of calcium carbonate and clay have been considered. Reference has been made to earlier work in which conditions of equilibrium in respect to carbon dioxide pressure, so vital in studies of this nature, have been overlooked. The absorption of Ca by a hydrogen colloidal clay from an excess quantity of $CaCO_3$ at different CO_2 pressures has been proposed for clearing up some of the problems in the study of the clay-$CaCO_3$ system. Methods for these studies have been described.

Equilibrium in the clay-$CaCO_3$-H_2O-CO_2 system can be established within 12 to 15 hours when $Ca(OH)_2$ or CaO is used as a source of Ca.

The pH values observed in $CaCO_3$-H_2O-CO_2 systems agree very well with the calculated values obtained by the use of accepted solubility values. The pH values of clay-$CaCO_3$-H_2O-CO_2 systems are higher than pH values of corresponding $CaCO_3$-H_2O-CO_2 systems making improbable the earlier assumption that soil has no effect on the HCO_3^-concentration.

The CO_2 pressure does affect the absorption of calcium by a hydrogen clay. Increase in CO_2 pressure in $CaCO_3$-H_2O-CO_2 systems increases the relative concentration of H ions much more than it does

the Ca-ion concentration. This increase in H-ion concentration, coupled with its much greater specific absorbability, accounts for the decrease in Ca absorption as the CO_2 pressure is increased.

It is shown that over the lower CO_2 pressures, this change in Ca absorption is a linear function of the cube root of the CO_2 pressure expressed in atmospheres.

The small quantity of data presented does not warrant more specific conclusions, especially in view of many inconsistencies. Further study should be made to establish definitely or disprove the relationships suggested.

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A STUDY OF HIGH AND LOW LEVELS OF SOIL FERTILITY RESPONSE TO TWO VARIETIES OF SUGAR BEETS[1]

L. A. HURST, A. W. SKUDERNA, AND C. W. DOXTATOR[2]

THE reactivity of certain commercial varieties of sugar beets to varying levels of soil fertility has long been observed by trained investigators, sugar company fieldmen, and farmers engaged in growing this crop. European beet seed firms engaged in the business of supplying the United States trade with beet seed, sought to meet the need by furnishing a choice of varieties listed as tonnage, intermediate and sugar types, designed to meet the varying needs of soil and climatic conditions of the areas where sugar beets are grown.[3] More recently with the development of domestic varieties of sugar beets, either resistant to certain diseases or better adapted to certain areas—to the extent that more than 85% of domestic needs for beet seed is now supplied through home sources—the number of varieties has been reduced, making it necessary to develop a more adequate program of soil fertilization fitted to the variety or varieties found best for any one area.

To this end the present study, which is a forerunner of other studies that are to follow, was undertaken. The results presented herein are therefore to be considered in the nature of a progress report.

EXPERIMENTAL PROCEDURE

The soil type on which this study was conducted was classified as Rocky Ford fine sandy loam with a pH of 7.5. The field was broken out of alfalfa in 1935 and planted to barley in 1936 and to onions in 1937. In the fall of 1937 an 8-ton coating of cattle manure was applied per acre immediately prior to fall plowing.

In the spring of 1938 the field was prepared for planting. Two domestic varieties of sugar beets were used, one being a "sugar" variety and the other a "tonnage" variety. Both of these varieties were somewhat more uniform as to type than the European varieties used in previous tests.

The commercial fertilizers used were 4–16–4, 4–16–0, 0–16–4, and 0–16–0, in comparison with the unfertilized check plats. The same amount of plant food per acre was applied from each mixture assuring thereby a comparison of equal amounts of plant food regardless of the difference in formula used. The rates of application for each fertilizer formula were 200, 400, and 600 pounds per acre of the equivalent of a 20% mixture, or 40, 80, and 120 pounds per acre, respectively, of total plant food. All the fertilizer was applied with the seed at time of planting.

The plat arrangement was fully randomized and of such layout as to permit unbiased evaluation of interactions between varieties, treatments, and rates of fertilizer application. Each treatment was replicated seven fold, the plats being

[1]This study was conducted in cooperation with the Division of Soil Fertility Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture, and the American Crystal Sugar Co., Rocky Ford, Colorado.

[2]Biochemist, Division of Soil Fertility Investigations and General Manager and Plant Breeder, respectively, American Beet Seed Company.

[3]SKUDERNA, A. W., *et al.* Evaluation of sugar beet types in certain sugar beet growing districts in the U. S. U. S. D. A. Circ. 476. 1938.

four rows wide and 65 feet long. The distance between rows was 20 inches. Two hundred ten plats were included in the study.

The beets were thinned to a distance of 12 inches in the row and were grown to maturity under irrigation. The beets were harvested on a competitive basis and analyzed for sucrose by the usual cold water digestion method. The results in all cases represent an average of the seven replications. The data were analyzed by the variance method.

RESULTS

The results of this study are tabulated in Table 1 for the "sugar" variety and in Table 2 for the "tonnage" variety. The statistical tabulation is shown in Table 3.

TABLE 1.—*Results from fertilizer treatment with a "sugar" variety, Rocky Ford, 1938.*

Formula	Rate of application per acre			Average
	200 lbs.	400 lbs.	600 lbs.	
		Tons of Beets per Acre		
4-16-4	14.053	12.752	12.905	13.237
4-16-0	13.285	12.088	12.753	12.709
0-16-4	13.572	13.540	12.536	13.216
0-16-0	12.669	12.958	12.064	12.564
Average..........	13.395	12.835	12.565	12.932
Check...........	11.909	11.531	11.942	11.791
		Percentage Sucrose in the Beet		
4-16-4	15.477	15.468	15.517	15.487
4-16-0	15.627	15.114	15.232	15.324
0-16-4	15.329	15.702	15.355	15.462
0-16-0	15.770	15.535	15.488	15.598
Average..........	15.551	15.455	15.398	15.468
Check...........	15.325	15.164	15.303	15.264
		Pounds Sugar per Acre Yield		
4-16-4	4,350	3,945	4,005	4,100
4-16-0	4,152	3,654	3,885	3,897
0-16-4	4,161	4,252	3,850	4,088
0-16-0	3,996	4,026	3,737	3,920
Average..........	4,165	3,969	3,869	4,001
Check...........	3,650	3,494	3,655	3,600

DISCUSSION OF RESULTS

From a study of results in Table 3 it is observed that there is a significant difference between the tonnage and sugar varieties in tons of beets per acre. The difference amounts to 1.94 tons in favor of the tonnage variety as compared to a required significance of 1.23 tons for an average of four treatments. In spite of some very definite trends, fertilizer response was not found to be significant.

In percentage of sucrose there is a significant difference due to varieties. Despite the very definite trends of sucrose percentage values

TABLE 2.—*Results from fertilizer treatment with a "tonnage" variety, Rocky Ford, 1938.*

Formula	Rate of application per acre			Average
	200 lbs.	400 lbs.	600 lbs.	
	Tons of Beets per Acre			
4-16-4	14.934	15.755	15.825	15.505
4-16-0	13.706	15.309	15.516	14.844
0-16-4	13.446	14.160	16.127	14.578
0-16-0	15.591	15.069	15.341	15.334
Average..........	14.419	15.073	15.702	15.065
Check...........	13.546	14.337	13.303	13.729
	Percentage Sucrose in the Beet			
4-16-4	14.675	15.205	15.046	14.975
4-16-0	14.953	15.230	15.204	15.129
0-16-4	15.097	14.816	15.740	15.218
0-16-0	15.214	15.359	15.843	15.472
Average..........	14.985	15.153	15.458	15.200
Check...........	14.805	14.647	15.045	14.832
	Pounds Sugar per Acre Yield			
4-16-4	4,383	4,791	4,762	4,645
4-16-0	4,099	4,663	4,718	4,493
0-16-4	4,060	4,196	5,077	4,444
0-16-0	4,744	4,629	4,861	4,745
Average..........	4,322	4,570	4,855	4,582
Check...........	4,011	4,200	4,003	4,071

(Tables 1 and 2) the calculated F value for rate of application does not reach the 5% point of significance. In comparing the interaction of varieties and rates of application a significant difference of .57% sucrose is observed between the two varieties in the 200-pound rate. In the 400- and 600-pound rate no variety differences were observed.

In the sugar per acre yields in the "sugar" variety (Table 1) no significant differences with different rates of application were observed, although the general trend is downward. In the "tonnage" variety (Table 2) the trend is upward and does reach significant proportions. The 600-pound rate of application produced 533 pounds more sugar per acre when compared to the 200-pound rate application. No differences between varieties were observed in the 200-pound rate of application, but in the 400- and 600-pound rates differences of 601 pounds and 986 pounds, respectively, were found as compared to the 367 pounds required for significance.

It must be observed that, although the calculated F values in Table 3 are in many cases not significant and therefore observed differences lack significance, the difference in trend between varieties with different rates of fertilizer application are of great interest. The results obtained from these two varieties grown on low, medium, and high levels of soil fertility indicate that the feeding ability of the variety may be an important consideration in a sugar beet breeding and improvement program.

TABLE 3.—*Variance of yield, sucrose percentage, and sugar production per acre for kind and rate of application applied to two varieties of sugar beets.*

Variation due to	Tons beets per acre		Percentage sucrose		Pounds sugar per acre	
	Mean squares	F	Mean squares	F	Mean squares	F
Varieties	229.795	43.25†	4.785	13.25†	16,757,320	35.51†
Kinds of fertilizer	14.992	2.82	1.283	3.55†	1,823,385	3.86†
Rates of application	0.444	0.08	0.54	0.98	145,466	0.31
Varieties × kinds of fertilizer	2.752	0.52	0.309	0.86	304,595	0.65
Varieties × rates of application	12.588	2.37	1.155	3.20*	1,842,490	3.90*
Kinds fertilizer × rate of application	1.164	0.22	0.271	0.75	114,872	0.24
Varieties × kinds fertilizer × rate of application	9.999	1.88	1.302	3.61†	1,315,149	2.79†
Error	5.315	—	0.361	—	471,969	—
Required for significant individual treatment	2.46 tons	—	0.63%	—	734 lbs.	—
Required for average of 4 treatments	1.23 tons	—	0.32%	—	367 lbs.	—

*Significance beyond 5% point.
†Significance beyond 1% point.

SUMMARY

Two domestic varieties of sugar beets designated as a "sugar" and a "tonnage" variety were compared in their reaction to different fertilizers and to different rates of fertilizer application. It was found that with the 'sugar' variety 400 and 600 pounds per acre of fertilizer lowered performance insignificantly as compared with 200 pounds of fertilizer. With the 'tonnage' variety 400 and 600 pounds of fertilizer slightly increased yields, sugar percentage, and sugar per acre, although only the 600-pound application produced significant differences. Attention is called to the need of determining whether a variety is a "strong" or "weak" feeder so that a more adequate program of soil fertilization may be developed.

AVAILABILITY OF SOIL MOISTURE, PARTICULARLY AS AFFECTED BY DEPTH, IN THE SOIL OF THE KENTUCKY EXPERIMENT STATION FARM AT LEXINGTON[1]

P. E. KARRAKER AND C. E. BORTNER[2]

IN Bulletin 272 of the Kentucky Agricultural Experiment Station, data are given showing that in many years lack of moisture prevents corn yields on the Experiment Station farm from reaching the level made possible by the fertility of the soil and that the reason for this is the poor distribution of rainfall during the growing season. Obviously this moisture limit to crop yields also is affected by the extent to which crops can utilize water held in the soil at different depths.

The general belief probably is that most crops obtain water from the first 5 to 6 feet of soil mainly by penetration of roots into the deeper layers, capillary movement no longer being thought of much importance in this connection. The basis for believing that crops root effectively at 4 to 5 feet, as pointed out by other writers[3] is the result of extensive studies of root development made by Weaver and co-workers in soils of the subhumid section of the United States where, because of the open nature of the subsoil, it is to be expected that crops would root deeper than in most soils in the eastern part of the country.

By considering the amount of water the soil on the Experiment Station farm will hold in relation to the crop requirement, it is apparent either that the crop can use water only from a comparatively shallow surface layer or that most of the water in the soil is held so firmly that crops cannot get it. Assuming the capacity of the soil of the surface foot to hold and deliver water to the crop to be 20% of its dry weight (maximum field capacity, about 30%), the surface foot layer (weight per acre, 4,000,000 pounds) would furnish water equal to approximately 2.6 surface inches. Seemingly it should be able to deliver 2 inches of this amount sufficiently rapidly so that the crop would suffer very little for water during the time this is being used. Since during the period of greatest use by the corn crop probably not over 1 inch of water is being removed from the soil per week, the surface foot alone should furnish the crop with enough water for almost 2 weeks, which is approximately the length of time the corn crop at this state of growth will go without injury in fair weather.

The soil used for the agronomy work is Maury silt loam. The surface soil works as a mellow silt loam and the subsoil is friable and well drained. Limestone rock is reached at from 6 to 10 feet, openings into

[1]The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station, Lexington, Ky., and is published by permission of the Director. Received for publication March 31, 1939.

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[3]FARRIS, NOLAN F. Root habits of certain crops as observed in the humid soils of New Jersey. Soil Sci., 38:87–111. 1934.

SPRAGUE, HOWARD B. Root development of perennial grasses and its relation to soil conditions. Soil Sci., 36:189–209. 1933.

which facilitate good drainage; however, the entire profile is high in clay. Mechanical analyses were made of samples from a profile in the county in connection with the soil survey of Fayette County, Kentucky (Bureau of Chemistry and Soils, Series 1931, No. 25). The plow

TABLE 1.—*Rainfall at Lexington, Ky., January 1 to August 31, inches.*

Month	Weather Bureau, 1930	1936		50-year average to 1932
		Weather Bureau	Gauge on farm	
January	4.44	4.00	2.88	4.10
February	2.91	2.07	1.68	3.06
March	2.54	4.43	4.46	4.34
April 1	0.28	0.37	0.10	
2	0.06	0.05	0.29	
3	0.05	0.03	—	
4	—	0.02	—	
5	0.10	2.15	—	
6	0.11	0.22	2.39	
9	—	1.34	0.55	
10	—	0.15	0.82	
11	—	0.33	0.15	
12	—	0.01	0.39	
15	—	0.05	—	
16	0.01	—	0.06	
17	0.06	—	—	
20	0.01	—	—	
21	0.01	0.43	—	
22	—	—	0.47	
28	0.02	0.34	—	
29	0.15	0.27	0.55	
30	—	—	0.35	
April, total	0.81	5.76	6.12	3.37
May 1	—	0.07	—	
2	—	—	0.15	
10	0.02	0.03	—	
11	0.85	0.06	—	
13	0.51	0.92	0.98	
14	—	—	0.16	
17	0.95	0.01	—	
18	0.43	0.36	—	
19	0.45	0.01	0.47	
23	0.08	—	—	
29	0.06	—	—	
May, total	3.35	1.46	1.76	3.49
June 6	0.88	—	—	
7	—	1.06	0.58	
8	—	0.01	0.50	
11	—	0.04	—	
16	0.18	—	—	
17	0.26	—	—	
20	0.07	—	—	
24	0.50	—	—	
30	—	0.07	—	
June, total	1.89	1.18	1.08	3.95

TABLE 1.—*Concluded.*

Month	Weather Bureau, 1930	1936		50-year average to 1932
		Weather Bureau	Gauge on farm	
July 1	0.05	0.08	—	
2	—	0.01	0.13	
9	0.21	—	—	
10	—	0.02	—	
11	—	0.50	—	
12	0.03	—	0.54	
13	0.11	—	—	
14	—	0.04	—	
15	—	0.32	—	
16	—	0.56	1.01	
18	—	0.02	—	
24	—	0.33	0.48	
25	—	0.79	—	
26	0.05	0.07	0.98	
28	—	0.01	—	
July, total	0.45	2.85	3.14	3.94
August 4	—	0.01	—	
5	0.06	0.03	0.11	
6	0.06	0.42	0.25	
7	0.19	—	0.29	
8	0.12	—	—	
9	0.07	—	—	
10	0.07	0.01	—	
13	0.02	0.02	—	
14	0.81	—	—	
21	0.06	0.16	—	
22	0.06	0.03	—	
23	0.17	—	—	
27	—	0.52	—	
28	—	—	0.55	
29	—	0.06	—	
30	—	—	0.06	
August, total	1.69	1.26	1.26	3.40
Total for 8 months	18.08	23.01	22.38	29.65

layer contained 37.9% clay (<.005 mm) and the 34- to 66-inch layer 62.2% clay. As a measure of humus content, the acre plow layer on the farm contains 3,000 to 3,500 pounds of nitrogen.

The 1930 growing season was very dry in Kentucky and summer crops were almost an entire failure. The 1936 growing season was also quite dry and summer crops were greatly injured. Precipitation at Lexington from January 1 to August 31 in these years and on the average is shown in Table 1.

The 1930 data were taken from the records of the Weather Bureau station about 1 mile away and hence may have been somewhat different from the rainfall on the farm. In 1936, data also were obtained from a gauge on the farm near the areas sampled.

In both these years, the soil on the Experiment Station farm in different cropping areas was sampled by layers and moisture and

nitrate determined in each. In 1930 the samples were taken the first of August and in 1936 the last of July (23rd and 24th). The results are reported in Tables 2 and 3.

In 1930 the samples in the scraped area and under the bluegrass-white clover sod were composites of five cores; under the corn, of two cores; and under the alfalfa, of four cores. In 1936 all samples were composites of four cores and sampling was done to rock.

TABLE 2.—*Total water and nitrate nitrogen at different depths in the soil of the Kentucky Experiment Station farm from August 1, 1930, based on soil dried at 105°C.*

Depth sampled	No crop since 1923, kept scraped bare		Continuous bluegrass and white clover since 1923	
	Water, %	Nitrate nitrogen, ppm	Water, %	Nitrate nitrogen, ppm
0–3 in.	10.55	8.5	3.97	2.5
3–12 in.	14.58	6	5.81	2.5
1–2 ft.	18.54	5	9.62	Trace
2–3 ft.	22.25	4	16.49	0
3–4 ft.	23.67	6	25.68	0
4–5 ft.	26.60	8	31.49	1
5–6 ft.	31.26	12	33.09	0

Depth sampled	Corn sample taken 6 ins. from hills; rotation corn, wheat, sod crop		Corn sample taken where diagonals between adjoining hills cross		Alfalfa second year	
	Water, %	Nitrate nitrogen, ppm	Water, %	Nitrate nitrogen, ppm	Water, %	Nitrate nitrogen, ppm
0–7 in.	6.86	32	7.65	44.5	7.36	13.5
7–12 in.	9.53	3	9.97	4	6.96	4
12–18 in.	11.00	3	11.43	1.5		
18–24 in.	15.06	1.5	18.83	1.5	11.13	Trace
2–3 ft.	20.24	1.5	21.02	2	20.22	Trace
3–4 ft.	25.81	1.5	25.01	2.5	24.35	Trace
4–5 ft.	30.57	2	28.99	1	28.60	Trace
5–6 ft.	33.66	2.5	34.03	3.5	31.73	Trace

Other determinations of total water in the soil on the Experiment Station farm, made in connection with various studies, show that the maximum field capacity of the soil of the plow layer is about 30%, of the remainder of the surface foot 2 or 3% less, probably because of a lower humus content, and below the surface foot 28 to 30% again, increased clay content here offsetting decreased humus. The hygroscopic coefficient determined over water in one sample each of the plow layer and the 24- to 30-inch layer is 7.12% and 14.24%, respectively.

In general the data (Tables 2 and 3) are similar for the two years. In both years, below 4 to 5 feet the soil contains approximately its maximum field capacity and above this, in most areas, there is a gradual decrease to 20 to 22% in the 2- to 3-foot depth, the decrease

being nearly the same in the uncropped and cropped areas. There is a further decrease in the top 2 feet. Excepting the samples taken from midway between corn hills in 1936, this is considerably greater in the cropped areas than in the uncropped areas. This indicates that in

TABLE 3.—*Total water and nitrate nitrogen at different depths in the soil of the Kentucky Experiment Station farm the last of July, 1936, based on soil dried at 105°C.*

Depth sampled	Fallow, in various sod crops for several years previous		Bluegrass-white clover since 1927	
	Water, %	Nitrate nitrogen, ppm	Water, %	Nitrate nitrogen, ppm
0–7 ins.	12.35	2.05	12.35	8
7–12 ins.	15.20	6	10.86	3
1–2 ft.	17.92	2	13.63	Trace
2–3 ft.	20.48	2.5	19.47	None
3–4 ft.	21.95	3	22.85	None
4–5 ft.	22.24	3	24.85	None
5–6 ft.	21.80*	2.5	28.86	None
6–7 ft.	27.22	3.5	30.20	None
7–8 ft.	28.53	2.5	30.89	None
8–9 ft.	29.03	1.5	28.70	None
9–10 ft.	—	—	27.87	None

Depth sampled	Corn sample taken 8 ins. from hills; rotation corn, wheat, sod crop		Corn sample taken where diagonals between adjoining hills cross		Alfalfa third year	
	Water, %	Nitrate nitrogen, ppm	Water, %	Nitrate nitrogen, ppm	Water, %	Nitrate nitrogen, ppm
0–7 ins.	9.64	32	18.76	20.5	10.13	15
7–12 ins.	11.60	7.5	15.07	6	11.35	4
1–2 ft.	15.30	1	18.06	2	13.76	1.5
2–3 ft.	21.50	2.5	22.69	Trace	18.06	Trace
3–4 ft.	23.76	None	23.60	None	24.53	None
4–5 ft.	25.00	None	25.47	None	28.53	None
5–6 ft.	27.87	None	28.04	None	26.58	None
6–7 ft.	28.88	None	28.86	None	20.91	None
7–8 ft.	28.70	None	30.89	None	18.34	Trace
8–9 ft.	28.88	None	30.89	None	20.91†	Trace
9–10 ft.	31.06 (rock at 9½ ft.)	Trace	32.98	None	—	—
10 ft.			31.75 (rock at 10½ ft.)	None		

*This figure appears to be out of line for some unknown reason.
†Considerable concretionary material was present in the bottom layers of the soil in this area which probably accounts for the lower percentages here.

both years the crops took most of their water from the top 2 feet of soil. However, the sod crop took some water from the 2- to 3-foot depth in 1930 and a small amount from this depth in 1936, and the alfalfa took some from this depth in both years. It should be considered that the crops no doubt reduced evaporation somewhat on

the cropped areas below that on the uncropped areas so that, even though there was no greater reduction in soil moisture below 2 feet in the cropped than in the uncropped areas, some water may have been obtained by the crop from this depth.

In connection with these field studies a quantity of soil was taken from the plow layer and also from the 24- to 30-inch layer and corn plants grown in these lots in ½-gallon, glazed earthernware jars to find out how much of the water in the soil was unavailable to the plants. The soils used for determination of hygroscopic coefficient reported above were from these lots. The subsoil was used in two conditions, *viz.*, pulverized and in blocks. There were four jars for the surface soil and for each of the subsoil conditions. Fifteen hundred grams of air-dry soil were used in each jar of the surface soil and pulverized subsoil. One block of the subsoil was used in each of these jars, the blocks varying in weight from 1,303 to 1,843 grams. After the soil was placed in the jars, water equal to 25% of the weight of soil and 1 gram of KNO_3 per jar were added. Because of the high phosphorus content of the soil no phosphate was added. To check on evenness of distribution of nitrate through the blocks, and because any unevenness might affect root distribution, blocks were placed in two additional jars and nitrate added as above. After 7 days nitrate was determined in the outside ½-inch layer and in the inside of the block from these jars. As an average of the two jars the nitrate in the outside layer, stated as pounds of nitrate-nitrogen per 2 million pounds of dry soil was 185, and in the inside part, 191.

Five grains of first generation hybrid corn were planted in each jar but in four of the jars only four plants grew. Fine gravel was filled in around the blocks of soil in the jars where the subsoil was not pulverized and placed as a mulch on all the jars. Later, sand was placed on top of this. During the first part of the experiment the jars were in the greenhouse; later, to prevent temporary wilting during bright days and to obtain more even temperatures, the jars were moved to the northern exposure of a well-lighted room. The corn was planted March 6, 1937, and the experiment terminated April 29. At this time all plants were dead in the jars containing the subsoil and all either had just died or were almost dead in the jars containing the surface soil. Most of the plants were living in all jars on April 12. The roots were mainly on the outside of the blocks of subsoil but were well distributed through the soil in the other jars although they were somewhat more numerous in the top than in the bottom half in most jars.

Capillary and hygroscopic water were determined in the soil of the jars, the top and bottom halves being sampled separately. There was very little difference between the two halves. Averaging the four jars in each experimental condition, the total percentages of water were as follows, the percentage of the hygroscopic water (soil dried at 105° C) also is shown.

	Total %	Hygroscopic %
Surface soil	12.0	4.5
Subsoil, pulverized	23.1	7.2
Subsoil, in blocks	24.0	7.1

It will be noted that in both dry years the water in the surface foot under the crops was below the above surface soil percentage, except in 1938 midway between the hills of corn. Considering the 2- to 3-foot depth, it will be noted that in both the cropped and uncropped land, the amount in the field is below the subsoil percentage above and, as noted previously, there was no great difference between the cropped and uncropped areas in the amount of moisture present. How much of this reduced amount in the field is due to the crop and how much to evaporation cannot be said, although the effect of the crop on the layers under the surface seems to be much less than expected.

Some observations of root development were made in both years. In 1930, 6 days after the soil was sampled for the moisture determinations, a trench was dug to a depth of 38 inches with a vertical face directly under a hill of corn in the area sampled and extending midway to the hill on either side. Most of the roots were in the plow layer. Only a few extended below 30 inches and very few below 38 inches and these were very small. Below the plow layer there was a gradual but fairly rapid decrease in roots with depth. When the sampling for moisture was done, the corn plants, two in each hill, averaged 6 feet high and 1 inch in diameter near the base. They were in tassel and many were silking. They showed serious drought injury. The crop, Boone County White, was planted May 5. Showers in May and the first of June made fair growth possible the first of the season. There was no yield of grain, however, on account of lack of rain in July and August.

In 1936, at the time the soil was sampled for determination of moisture, observations were similarly made of root development in another plat of corn on the farm. While classified as Maury silt loam, the subsoil here is not as friable as in the areas sampled for moisture. The roots were mainly in the plow layer and decreased very rapidly below this to 10 inches and gradually below this. Few roots were observed below 24 inches and very few below 32 inches (the greatest depth of observation). The total moisture in samples of soil from locations 15 inches from hills (average of two locations) was determined. The percentages found were 0 to 12 inches, 13.25; 12 to 24 inches, 15.87; 24 to 36 inches, 18.90; and 36 to 42 inches, 21.21. The corn, Midland Yellow Dent, in the area sampled for determination of moisture (1936) was planted May 6. It yielded 22.9 bushels grain per acre. At the time of sampling the stalks averaged 55 inches high and ¾ to 1 inch in diameter at the base. There were two to three stalks per hill. In years of normal rainfall corn plants grow larger than the plants in these two dry years and hence probably have larger root systems; however, in both dry years the plants made fair growth up to tasseling time.

In 1936 root development also was observed under an old bluegrass-white clover soil. Most of the roots were in the surface 4 inches of soil but were numerous to a depth of 10 inches and thereafter decreased rapidly to almost none below 24 inches. The percentage of total water found in a sample removed from the 24- to 26-inch depth was 21.50.

In some casual observations not made in connection with these studies, it was observed that alfalfa roots penetrated 6 to 7 feet to rock in one area on the farm.

The data indicate rather clearly that the crops obtained no great amount of water below the 2-foot soil depth. This can be attributed in whole or in part to the failure of the crops to root effectively below this depth. To a considerable extent it also could be attributed to the strong pull of the soil of the under layers for water because of the high clay content, as a consequence of which the amount of water in these layers between that apparently unavailable to the crop and the maximum field capacity of the soil is relatively small. Perhaps the failure of the crops to root more extensively in these layers is partly due to their inability to get more water from them.

It was thought that distribution of nitrate (Tables 2 and 3) might give some additional information on moisture movement. For the most part it did not, but in 1930, in the scraped area, the decrease in nitrate content to the 2- to 3-foot depth and then an increase below this perhaps suggests that the 2- to 3-foot depth was the lower limit of movement to the surface. In passing it may be noted that the unfavorable moisture condition did not reduce nitrate production as much as it did crop growth since nitrate was higher under the crops than is expected in normal years.

It is not known how injury from lack of moisture to summer crops on the Maury silt loam compares with that on other soils in the state. Observations on the outlying experiment fields, however, indicate that there are considerable differences between soils in the state in this respect and that crops suffer from lack of rain as quickly on the Maury silt loam as on any other extensive type in the state. J. F. Freeman, superintendent of the outlying fields, has observed that on the Western Kentucky Substation at Princeton, corn on soil derived mainly from shale and sandstone (probably Tilsit silt loam) is injured less by drought than on another part of the farm where the soil is derived mainly from limestone (probably Decatur silt loam). The limestone soil is better drained than the other, but the under layers are much higher in clay, being comparable with the Maury silt loam in this respect. Observations of root penetration have not been made at any of the outlying fields.

SUMMARY

Data are reported of the moisture in different layers of Maury silt loam soil on the Kentucky Experiment Station farm in variously cropped and uncropped land in the dry years of 1930 and 1936. Below 4 or 5 feet the soil contained approximately its maximum field capacity. Above this, moisture decreased towards the surface but below 2 to 3 feet no faster in the cropped than the uncropped areas. Above 2 to 3 feet the decrease was considerably greater in the cropped than in the uncropped areas. This indicates that the crops obtained water chiefly from the top 2 to 3 feet. Observations of depth of root penetration showed that the crops did not root effectively below this depth. In pot experiments, 12% of water in the surface soil and 23 to 24% in the subsoil was unavailable to corn plants so that even if crops rooted extensively in under soil layers, the amount of water obtained here would not be great.

AGRONOMIC AFFAIRS

TENTATIVE PROGRAM FOR THE ANNUAL MEETING OF THE SOCIETY AT NEW ORLEANS

As a result of the "show of hands" at the last annual banquet of the Society, the Executive Committee has scheduled the next annual meeting at New Orleans, November 22, 23, and 24, with the Hotel Roosevelt as headquarters. Considerable progress has been made in making up the program.

Inasmuch as the Society has not met in the South for a number of years, it seemed appropriate that the general program should be concerned with southern agriculture. Accordingly two eminent authorities have been invited to address the general session. Dean M. J. Funchess of Alabama, a past president of the Society, will speak on the subject "Agronomic Problems of the South", and Mr. W. C. Lassetter of Tennessee, Editor of the *Progressive Farmer*, will speak on "The Social and Economic Problems of Southern Agriculturists".

The main speaker at the annual banquet of the Soil Science Society of America will be Professor G. W. Robinson, University of North Wales. His subject will be announced later.

In arranging the sectional programs for a group with so many common and diverse interests as the agronomists, there is bound to occur some overlapping in subject matter. As far as the annual meeting is concerned the division of the Society into a Crops Section and a Soils Section is largely for convenience in program building. Some subjects listed under the Crops Section are of almost equal interest to the soils group. The reverse is also undoubtedly true. For example, "Teaching and Extension", listed under the present tentative crops program, is of equal interest to the soils group and might just as logically be listed under the Soils Section. Any member of the Society, regardless of whether he is primarily interested in soils or crops, is, of course, free to submit a research paper before either of the Sections of the Society by making the necessary arrangements with the respective chairmen.

CROPS SECTION

Dr. F. D. Keim, chairman of the Crops Section, has submitted the following tentative outline showing the various sessions which have been arranged and the names of the respective chairmen.

Subsection I: Breeding, Genetics, and Cytology.
- Chairman, H. H. Love, Cornell University.
- Session A—Statistics.
  - Chairman, Karl S. Quisenberry, Bureau of Plant Industry and Nebraska Agricultural Experiment Station.
- Session B—Cotton Breeding and Genetics.
  - Chairman, H. B. Brown, Louisiana Agricultural College.

Session C—Corn Genetics.
Chairman, P. C. Mangelsdorf, Texas A. and M. College.
Session D—Rice and Sugar Improvement.
Chairman, Jenkin W. Jones, Bureau of Plant Industry.

Subsection II: Physiology, Morphology (including Nutrition), and Taxonomy.
Chairman, O. W. Dynes, University of Tennessee.
Session A—Ecological Relations of Crop Plants.
Chairman, F. D. Keim, University of Nebraska.
Session B—Crop-Weather Relations.
Chairman, H. H. Laude, Kansas State College.
Session C—The Nutritive Value of Forage Plants Grown Under Various Conditions and for Different Classes of Livestock.
Chairman, O. McConkey, Ontario Agricultural College.
Session D—Cotton Fertilizers and Diseases.
Chairman, D. G. Sturkie, Alabama Polytechnic Institute.

Subsection III: All Other Phases.
Chairman, F. D. Keim, University of Nebraska.
Session A—Cotton Regional Variety Tests.
Chairman Henry W. Barre, Bureau of Plant Industry.
1. Field results
2. Laboratory tests
3. Spinning tests
4. Exhibits

Session B—The Coordinated Agronomic Program of the T. V. A.
Chairman, T. B. Hutcheson, Virginia Polytechnic Institute.
Session C—Teaching and Extension.
Chairman, J. C. Lowry, Alabama College of Agriculture.
Session D—Cotton Fibers and Ginning and Spinning Studies.
Chairman, Ide P. Trotter, Texas A. and M. College.
1. Work in Webb's laboratory
2. Stoneville's ginning laboratory
3. Discussion and demonstration of various cotton sorters.
   (a) Presley's.
   (b) Hertel and Hancock.
   (c) Johnson's.
   (d) Suter-Webb.

Session E—Miscellaneous.
Chairman, F. D. Keim, University of Nebraska.

SOILS SECTION

Dr. William A. Albrecht, chairman of the Soils Section, has submitted a similar, although somewhat more condensed, program for the Soil Science Society of America.

Section I—Soil Physics. Miscellaneous Papers.
Chairman, G. B. Bodman, University of California.

Section II—Soil Chemistry. Miscellaneous Papers.
Chairman, J. W. Tidmore, Alabama Polytechnic Institute.

Section III—No program will be held at New Orleans in consequence of the program at New Brunswick in connection with the International Congress of Microbiology.
Chairman, A. W. Hofer, New York Agricultural Experiment Station.

Section IV—Soil Fertility. Joint Session with Crops Section.
Subject: Cotton Diseases and Fertilization.
Symposium: The Effects of Boron in Agriculture.
Chairman, J. J. Skinner, Bureau of Plant Industry.

Section V—New Developments in Soil Mapping. Forest Soils Program. Miscellaneous Papers.
Chairman, S. S. Obenshain, Virginia Polytechnic Institute.

Section VI—Changes in Soils in Consequence of (1) Irrigation, (2) Drainage, (3) Erosion, and (4) Cultivation and Fertilization. Miscellaneous Papers.
Chairman, W. L. Powers, Oregon State Agricultural College.

The program of the general meeting of the Soil Science Society of America will consist of six papers, one contributed by each of the respective sections of the Society.

The respective chairmen of the Soils Section desire to extend their call for papers and bring to attention the date of September 15 as the final date for submission of titles and abstracts. Detailed information on program regulations governing papers presented before the Soil Science Society appear on page 360 of the 1938 PROCEEDINGS.

REGISTRATION FEE

A nominal registration fee will be charged for the first time at the New Orleans meeting to help defray expenses incurred in connection with the annual meeting. Entrance to the technical sessions of the American Society of Agronomy and of the Soil Science Society will be open only to registered individuals.

MEETING OF WESTERN BRANCH OF SOCIETY

THE twenty-third annual meeting of the Western Branch of the American Society of Agronomy was held at Davis and Berkeley, Calif., June 6 to 8. The entire day of June 6 at Davis was devoted to field trips. Wednesday and Thursday, June 7 and 8, at Berkeley were devoted to the presentation of the following papers:

Inheritance of resistance to mildew in barley in the cross Duplex×Atlas. E. H. Stanford, University of California.

Production of sugar beet seed. H. E. Finnell, Oregon State College.

The effect of differences in soil moisture on the yield and quality of alfalfa seed. Ian A. Briggs, University of Arizona.

The effect of frost and scald on the germination of barley. Dr. D. D. Hill, Oregon State College.

Recent developments in our weed research program. Dr. R. J. Evans, Utah State Agricultural College.

Determining by plant response the retention of nutrient ions by soils. Dr. John P. Conrad, University of California.

Sulfofication of soil organic matter and microbiological competition with plants for sulphates. Frank G. Viets and John P. Conrad, University of California.

The role of straw in erosion control. G. R. McDole, Pacific Northwest Region, Soil Conservation Service, U.S.D.A.

Some observations on the relation of cultural practices and the addition of certain carbohydrate materials to the nitrate-supplying power of peat soils. Dr. R. A. Pendleton, Assistant Soil Technologist, Bureau of Plant Industry, U.S.D.A.

Early agricultural history in California as revealed by adobe bricks. Geo. W. Hendry, University of California.

Cooperative research between research specialists and the Extension Division in California. Burle J. Jones, University of California.

Some distinctive features of the seed certification program in California. Frank G. Parsons, University of California.

The business meeting was held on board a river steamer while enroute overnight from Sacramento to San Francisco. Dr. R. J. Evans of Utah, president of the Western Branch, was taken ill on his way to the meetings and could not attend. Officers elected for the coming year are G. R. Hyslop, Oregon State College, president; and D. C. Tingey, Utah Agricultural College, secretary. The 1940 meeting will be held at Logan, Utah.—COIT A. SUNESON, *Secretary*.

NEWS ITEMS

G. N. HOFFER, Midwest Manager of the American Potash Institute, was given the honorary degree of Doctor of Science by Purdue University on June 11. Doctor Hoffer was a member of the Purdue staff for twenty years prior to entering the service of the Institute.

ACCORDING to *Science*, Dr. S. A. Waksman, microbiologist at the New Jersey Experiment Station, has been elected a foreign member of the Royal Swedish Academy of Agriculture.

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THE EFFECT OF OXIDATION-REDUCTION POTENTIAL ON PLANT GROWTH[1]

N. J. VOLK[2]

A STUDY of the literature reveals that considerable controversy exists as regards the effect of soil Eh on plant growth. Bradfield and his co-workers (1)[3] found that the productiveness of apple trees in New York State was related to the Eh of the soils, but Stephenson and his associates (4) concluded that no such relation existed in Oregon. Sturgis (5), working with rice in Louisiana, discovered a close relationship between active organic matter and reduction in water-logged soils, but could not use the resultant Eh values of soils to predict yields of rice.

The Eh of arable Alabama soils fluctuated only about 40 to 80 millivolts during an entire year (6), and it seemed highly desirable to determine whether or not such small changes would have an effect on plant growth. The purpose of this paper is to present data obtained from greenhouse studies regarding the effect of the Eh of a nutrient solution on plant growth when oxygen was not a limiting factor.

METHOD OF INVESTIGATION

In determining the effect of the Eh and only the Eh on plant growth, it is necessary to have all factors constant except Eh, and for this reason soils could not be used since factors other than Eh, such as available oxygen, could not be controlled. Quartz sand cultures, however, were found to be satisfactory. Nutrient solution was run through the sand at such a rate that the growing plants did not appreciably change its Eh value during the entire growing period. No attempt was made to deprive the plants of oxygen.

The composition of the base nutrient solution was prepared from salts as follows:

0.056 gram boric acid C. P.
4.70 grams $CaCl_2.2H_2O$ C. P.
13.78 grams $MgSO_4.7H_2O$ C. P.
4.35 grams KH_2PO_4 C. P.
6.45 grams $NaNO_3$ (commercial)
0.034 gram $MnSO_4.2H_2O$ C. P.

[1]Contribution from the Department of Agronomy and Soils, Alabama Agricultural Experiment Station, Auburn, Ala. Published with the approval of the Director. Received for publication March 30, 1939.

[2]Soil Chemist.

[3]Reference by number is to "Literature Cited", p. 670.

This was made up to 20 liters and adjusted to pH 6.0 with H_2SO_4.

To vary the Eh of the above nutrient solution it was necessary to add something that would not alter its nutrient value. A great many organic compounds were tested for their toxicity to plants at various concentrations and for their

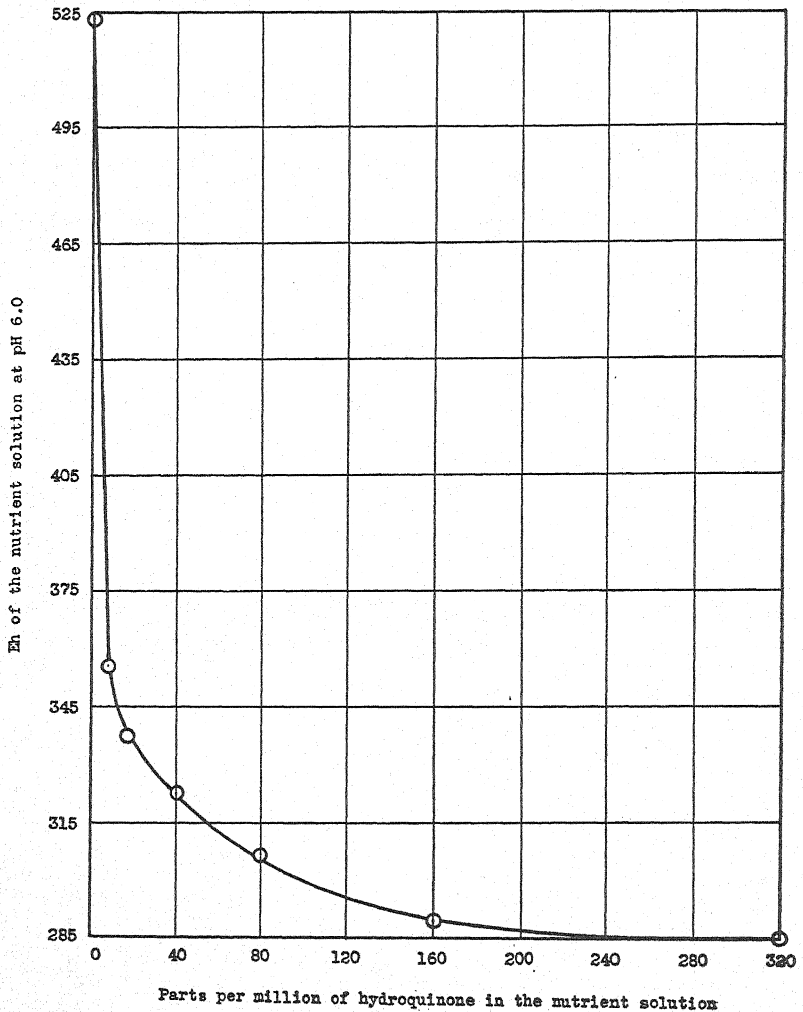

FIG. 1.—The effect of hydroquinone on the Eh value of the nutrient solution.

power to alter the Eh of the solution. Hydroquinone was found to be very suitable in small quantities. The range in Eh of 35 different batches of nutrient solution is shown in Table 1 and Fig. 1. It is evident that the magnitude of the change in Eh decreases rapidly with increasing increments of hydroquinone up to 10 ppm, and that the decrease thereafter is moderately slow.

TABLE 1.—*The Eh value of nutrient solution containing different amounts of hydroquinone.*

Nutrient solution plus	Eh of solution in millivolts at pH 6.0				
	Test 1	Test 2	Test 3	Test 4	Test 5
No hydroquinone	521	520	526	524	524
10 ppm hydroquinone	354	355	357	357	356
20 ppm hydroquinone	336	337	341	340	338
40 ppm hydroquinone	319	324	325	319	323
80 ppm hydroquinone	306	307	308	307	308
160 ppm hydroquinone	294	291	291	290	291
320 ppm hydroquinone	284	281	281	287	285

Thirteen different crop plants were used in studying the effect of Eh on plant growth as follows: Sorghum, sudan grass, corn, sunflower, cotton, tomatoes, vetch, string beans, cowpeas, soybeans, crotalaria, alfalfa, and garden peas.

The aim, during the growth of the plants, was to maintain three cultures at an Eh between 500 and 550 millivolts, which is about normal for most arable Alabama soils, and three cultures between 325 and 350 millivolts, which is 100 to 150 millivolts below the lowest point reached by an arable Alabama soil tested during 1937 (6). Since the Eh of the base nutrient solution was about 525, one set of three cultures was kept between 500 and 550 millivolts simply by passing the nutrient solution through the sand cultures at a rate that would maintain a constant Eh. In the case of the cultures held at an Eh value below 350 millivolts, it was found necessary to start the seedlings with a nutrient solution containing only 15 ppm of hydroquinone (Eh between 330 and 350). When tests of the waste solution showed that the Eh was being raised above 350 millivolts by the plants, either the speed with which the nutrient solution was passed through the sand was increased, or a little more hydroquinone was added. Because of the toxic effect, very few plants could stand more than 15 ppm of hydroquinone in the seedling stage or more than 60 to 70 ppm in later stages; hence in many cases several gallons of solution containing only a small amount of hydroquinone had to be run through the cultures daily to maintain a constant Eh below 350 millivolts. The quantity of nutrient solution passed through an individual culture was at no time less than 6 liters a day.

To preclude the accumulation of salts in the sand, the cultures were flushed daily with 2 liters of distilled water followed immediately by 2 liters of the particular nutrient solution being used on that pot. This procedure caused the plants to be out of contact with the nutrient solution only about 5 minutes. The Eh of the waste nutrient solution escaping from the sand cultures was tested daily and any necessary adjustments made to maintain the desired Eh. All solutions were in equilibrium with the air at all times, thus oxygen was not a limiting factor in the growth of the plants. By the above procedure it is believed that the plant roots were at all times bathed in a solution of desired Eh value and yet were supplied with all the necessary plant food elements including a supply of available oxygen.

RESULTS AND DISCUSSIONS

For the 13 crops tested, no detrimental effects were observed when the Eh of the nutrient solution was lowered from about 525 millivolts to about 325 millivolts (Figs. 2, 3, and 4 and Table 2). Since an Eh value of 325 is roughly 150 millivolts below the Eh reached by

any arable Alabama soil tested during 1937 (6), it appears quite probable that the small variations in oxidation-reduction *potential* observed in arable Alabama soils has little or no effect on plant growth. Of course, since potentials only as low as 325 were studied at this time, nothing can be said of the effect of the extremely low potentials reported by Peech and Boynton (2). The fact that a redox potential of 325 has not affected the plants tested does not in any sense infer that changes in factors closely associated with it, such as

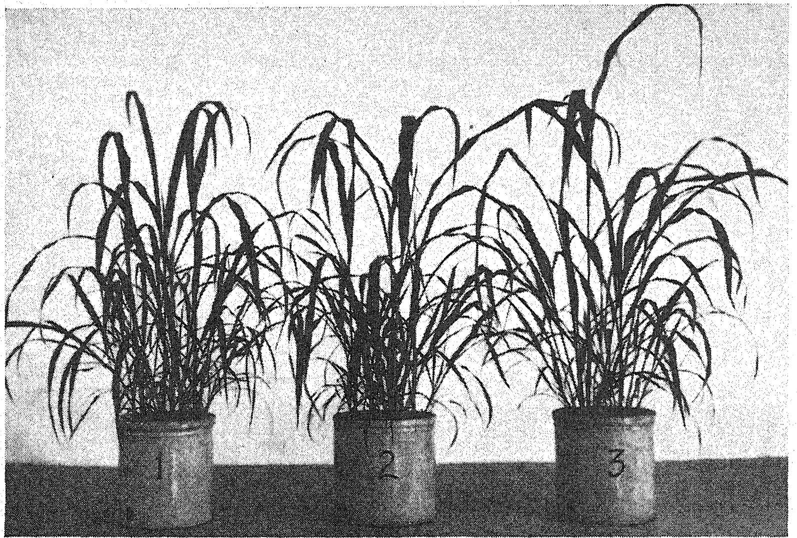

FIG. 2.—Sudan grass grown in pots 1 and 3 at an Eh between 500 and 550 millivolts and in pot 2 at an Eh between 325 and 350 millivolts, all at pH 6.0.

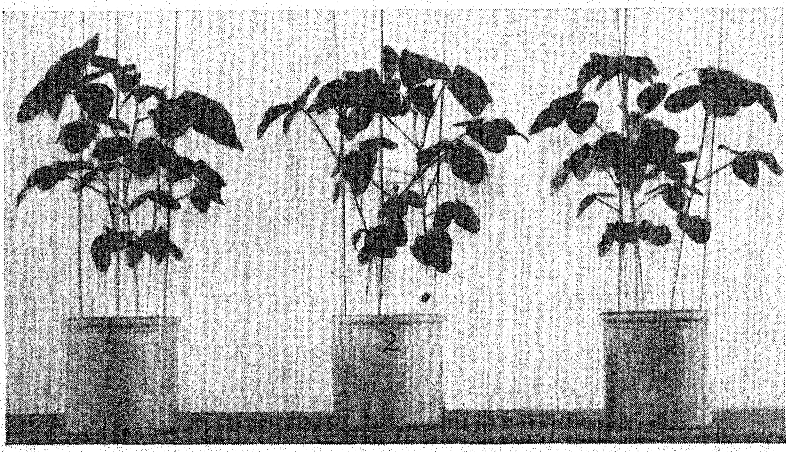

FIG. 3.—Soybeans grown in pots 1 and 3 at an Eh between 500 and 550 millivolts and in pot 2 at an Eh between 325 and 350 millivolts, all at pH 6.0.

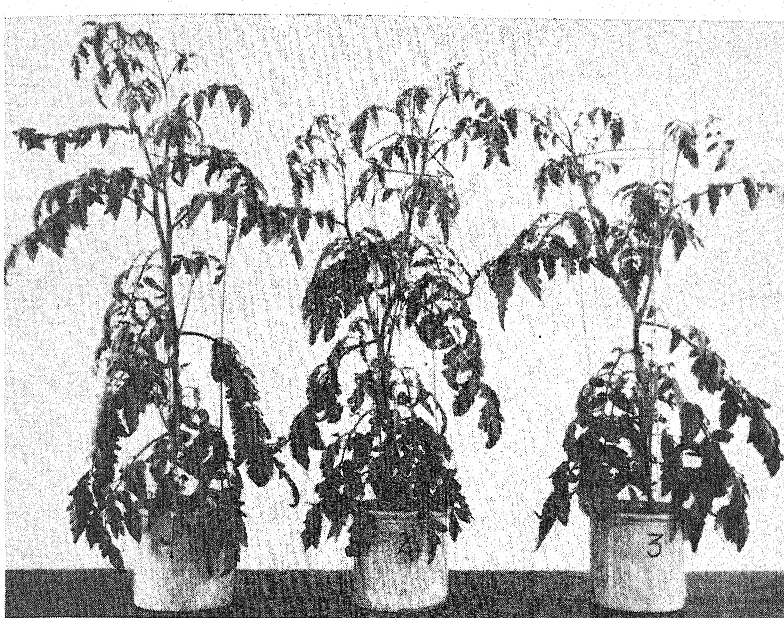

FIG. 4.—Tomatoes grown in pots 1 and 3 at an Eh between 500 and 550 millivolts and in pot 2 at an Eh between 325 and 350 millivolts, all at pH 6.0.

the lack of available oxygen, reduction, oxidation, toxic substances, etc., will not affect plants. The work of Peech and Boynton (2) and of Bradfield, Batjer, and Oskamp (1) certainly indicates that some factor is affecting plant growth in water-logged soils, but whether

TABLE 2.—*Amounts of plant material produced at different Eh values in constant flow nutrient solution in sand cultures.*

Plants grown in nutrient solution	Dry weight of plants in grams	
	Nutrient solution Eh 525	Nutrient solution Eh 325 to 350
Sudan grass	28.7	27.5
Sorghum	33.5	33.7
Sunflower	37.4	37.5
Corn	37.0	35.5
Cotton	17.1	18.0
Alfalfa	22.0	23.0
Garden peas	7.9	8.0
Crotalaria	23.0	26.0
String beans	7.8	7.3
Soybeans	16.1	16.5
Cowpeas	16.6	17.0
Vetch	6.5	6.0
Tomatoes	64.5	58.5
Total dry weight of plants	318.1	314.5

or not it is strictly the Eh remains to be proved in the case of extremely low potentials. The work of Schreiner and Sullivan (3) indicates that soil oxygen may play an important part.

Single isolated soil Eh values reveal very little regarding the state of oxidation or reduction in a particular soil under field conditions. When the Eh value is obtained it is known that a particular soil at the time of testing had a certain Eh value, but an interpretation cannot be made within narrow limits as regards the state of oxidation or reduction of that soil as compared with some other soil since the kinds, relative amounts, and states of oxidation of the ions causing the resultant potentials are not known. A series of determinations, however, obtained over a period of time on a given soil would be more revealing as regards the state of oxidation or reduction (6).

CONCLUSIONS

A study was undertaken for the purpose of determining the effect of oxidation-reduction *potential*, within certain limits, on plant growth when oxygen was not a limiting factor. Thirteen different crops were tested using sand cultures and constant flow nutrient solutions of different Eh values but of constant nutrient value and in equilibrium with the air. No attempt was made to study changes in the state of oxidation or reduction, or other changes that might accompany changes of Eh in soils. In all tests it is believed that Eh was the only variable present.

The results show that for the plants tested, a change in Eh from about 525 millivolts to about 325 millivolts did not affect plant growth. An Eh of 325 millivolts is approximately 100 to 150 millivolts below the lowest Eh reached by 48 arable Alabama soils tested throughout the year 1937.

Oxidation-reduction potentials below 325 millivolts have not been studied by the method described herein.

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EFFECT OF AVAILABLE PHOSPHORUS IN SOUTHERN SOILS UPON CROP YIELDS[1]

CLARENCE DORMAN AND RUSSELL COLEMAN[2]

FINDING a way to obtain maximum benefit from applied phosphorus has become a major problem in agriculture. This problem is of particular importance to the South where many soils, although very low in dilute acid soluble phosphates, give little crop response when soluble phosphates are applied. Recent investigations (1, 2)[3] have indicated that this lack of crop response is due to a rapid fixation of applied phosphorus into forms which are unavailable to plants. Ford (3) and others (5) have found that calcium, iron, and aluminum are responsible for phosphorus being fixed into an insoluble form.

Phosphorus fixation varies greatly with different soils. Beater (1) found that the quantity of phosphorus fixed is roughly proportional to the amount of clay present. Scarseth and Tidmore (9) report large amounts of phosphorus fixed by soil colloids, and suggest that phosphorus application should be based on the amount of colloids present. They found that an application of 2,000 pounds of superphosphate per acre to a soil with 60% colloid material was equivalent to 300 pounds applied to a soil with 9% colloidal material.

The work of Heck (5) indicates that phosphorus is fixed much more rapidly in some soils than in others; therefore, it seems evident that no general recommendations may be made for phosphorus fertilization. Each soil presents its particular problems and should be treated according to its specific needs. Some southern soils show a definite response to phosphorus while others show very little. Can the phosphate-deficient soils receive enough available phosphorus from light applications, or do they require heavy applications for maximum crop response? Evidently the answer to this question depends upon several factors, namely, the crop grown, the climate, and the nature of the soil. It is the purpose of this study to determine the phosphate requirements of several important southern soils and to suggest a method for recommending phosphate applications.

EXPERIMENTAL PROCEDURE

Both greenhouse and field studies were made on several soil types varying greatly in physical and chemical properties and representing a large number of southern soils.

Greenhouse Study.—Representative samples from the A horizon of Ruston, Orangeburg, and Susquehanna fine sandy loams were used. Four different samples of each soil type, taken from 12 widely separated areas, were removed to the greenhouse, and weighed into 3-gallon pots. The top 3 inches of the soil were removed, and after the fertilizer had been distributed evenly, the soil was replaced

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[3]Figures in parenthesis refer to "Literature Cited", p. 677.

in the pots, leaving the fertilizer 3 inches beneath the surface. Phosphorus was applied as mono-calcium phosphate, equivalent to 400, 800, and 1,600 pounds of 18% superphosphate. Nitrogen and potash were also applied in most treatments to eliminate them as variables.

The soils in the pots were held at optimum moisture content for two weeks, and at the end of this period available phosphorus was determined by the Truog method (10). Equilibrium between the soil and phosphorus should have been reached within this time, because other investigations (7, 9) have shown that the reaction between a soluble phosphate and the soil is practically instantaneous.

Two crops of sagrain (a grain sorghum) were used to measure crop response. The first crop was planted immediately after the available phosphorus was determined, and the second was planted in the same pots after the first crop was harvested.

Field Study.—Soils obtained from a cotton test previously conducted on 10 different soils, representing eight soil types, were used as a basis for this study. The soils represented are Ruston fine sandy loam, Oktibbeha clay, Grenada silt loam, Savannah very fine sandy loam, Cahaba fine sandy loam, Olivier silt loam, Houston clay loam, and Trinity fine sandy loam. Samples were taken from two plats in each of the 10 soils, one of which had received 400 pounds of 4–8–4 and the other 400 pounds of 4–0–4 per acre for five years. About 20 small samples were taken from the top soil of each plat and after these were mixed thoroughly into one composite sample, available phosphorus was determined on each by the Truog method. The average cotton yields on the 4–8–4 and 4–0–4 plats were calculated and compared with the amount of available phosphorus present.

RESULTS AND DISCUSSION

EFFECT OF AVAILABLE P_2O_5 IN SOIL UPON YIELD OF SAGRAIN

The data in Table 1 show the sagrain yields and available P_2O_5 in pots which had received different phosphate treatments. The untreated pots show a great difference in the fertility of the same soil type taken from different locations, which makes it very difficult to compare the productivity of soil types. It is interesting to observe, however, that Susquehanna fine sandy loam, a very poor agricultural soil, yielded as much sagrain in the greenhouse as Ruston and Orangeburg fine sandy loams, two highly productive soils.

Crop response to phosphorus was similar in 11 of the 12 soils studied in the greenhouse. All of the soils were originally low in available P_2O_5, none having over 6 ppm, and all except one gave an excellent response to phosphorus both when applied alone and when used with nitrogen and potash. Maximum response in almost every case was obtained when an equivalent of 400 pounds of superphosphate per acre was applied with 400 pounds of 4–0–4 fertilizer per acre, and hardly any additional response was obtained when equivalents of 800 and 1,600 pounds of superphosphate per acre were applied with 400 pounds of 4–0–4 per acre.

The results on Susquehanna fine sandy loam (No. 11) show that an increase from 3 to 10 ppm of available P_2O_5 increased the sagrain yield from 13.9 to 28.9 grams, but a further increase in available P_2O_5 failed to increase the yield. The soil containing 10 ppm available

TABLE I.—*Effect of available P_2O_5 upon the yield of sagrain.*

Soil No.	Observation	Fertilizer treatment*					
		400 lbs. 4-0-4	400 lbs. superphosphate and 400 lbs. 4-0-4	800 lbs. superphosphate and 400 lbs. 4-0-4	1,600 lbs. superphosphate and 400 lbs. 4-0-4	No fertilizer	800 lbs. superphosphate
	Susquehanna Fine Sandy Loam						
11	Dry weight in grams...	13.9	28.9	24.1	26.9	12.6	20.1
	Available P_2O_5 in ppm	3.0	10.0	18.0	42.0	—	—
12	Dry weight in grams...	15.6	25.4	24.8	25.6	13.9	20.2
	Available P_2O_5 in ppm	4.0	10.0	19.0	45.0	—	—
13	Dry weight in grams...	9.4	13.8	14.7	14.9	6.6	11.5
	Available P_2O_5 in ppm	6.0	17.0	21.0	42.0	—	—
14	Dry weight in grams...	20.2	24.4	21.7	20.6	13.6	16.1
	Available P_2O_5 in ppm	5.0	14.0	23.0	45.0	—	—
	Ruston Fine Sandy Loam						
15	Dry weight in grams...	14.2	22.6	21.8	21.5	10.8	11.7
	Available P_2O_5 in ppm	2.0	11.0	18.0	42.0	—	—
16	Dry weight in grams...	8.0	16.1	13.5	14.6	5.2	9.6
	Available P_2O_5 in ppm	2.0	8.0	12.0	32.0	—	—
17	Dry weight in grams...	14.9	17.0	20.6	19.8	10.0	14.5
	Available P_2O_5 in ppm	3.0	8.0	13.0	43.0	—	—
18	Dry weight in grams...	21.1	25.1	26.0	27.5	17.2	19.3
	Available P_2O_5 in ppm	3.0	8.0	22.0	35.0	—	—
	Orangeburg Fine Sandy Loam						
19	Dry weight in grams...	11.7	15.5	16.5	12.6	8.4	9.9
	Available P_2O_5 in ppm	5.0	18.0	15.0	38.0	—	—
20	Dry weight in grams...	19.4	19.1	22.9	19.5	16.5	14.8
	Available P_2O_5 in ppm	4.0	17.0	21.0	43.0	—	—
21	Dry weight in grams...	7.3	16.9	17.5	19.4	2.0	11.2
	Available P_2O_5 in ppm	2.0	8.0	11.0	22.0	—	—
22	Dry weight in grams...	26.9	31.2	29.8	27.9	16.2	23.0
	Available P_2O_5 in ppm	3.0	21.0	32.0	60.0	—	—

*Phosphorus applied as mono-calcium phosphate equivalent to superphosphate.

P_2O_5 yielded just as much as the one containing 42 ppm. The other three Susquehanna soils showed similar response.

The response of sagrain on Ruston and Orangeburg fine sandy loams was very similar to that obtained on Susquehanna. An increase from 2 to 8 ppm available P_2O_5 in Ruston fine sandy loam (No. 16) increased the sagrain yield from 8 to 16.1 grams, but an additional increase to 32 ppm failed to increase the yield of sagrain. Likewise an increase from 2 to 8 ppm available P_2O_5 in the Orangeburg sandy loam (No. 21) increased the sagrain yield from 7.3 to 16.9 grams, but additional increases in available P_2O_5 failed to increase crop yields. One soil containing only 6 ppm available P_2O_5 did not respond to any phosphate treatment.

The results show that soils with 5 and 6 ppm available P_2O_5 failed to give as much response to phosphate applications as those with only 2 and 3 ppm. Phosphorus applications increased the yield of sagrain on every soil except one, but after the available P_2O_5 in the soil had reached 10 or 15 ppm, greater applications of phosphorus failed to increase yields. Maximum yields were obtained on many soils with only 16 pounds (8 ppm) available P_2O_5 per acre, which is a lower requirement than most investigators have reported. Truog (10) has set the minimum limit of readily available phosphorus at 50 pounds per acre in the plowed layer of the sandy soils of Wisconsin. However, he suggested that 20 to 30 pounds may suffice for growing corn in certain sections of the South.

EFFECT OF AVAILABLE P_2O_5 IN SOIL UPON YIELD OF COTTON

The data in Table 2 show the available P_2O_5 and cotton yields on 10 different soils which had been treated with 400 pounds of 4–8–4

TABLE 2.—*Effect of available phosphorus upon the yield of cotton.*

Soil No.	Soil type	Fertilizer treatment, 400 lbs. per acre	Available P_2O_5, ppm	5-year average yield, lbs. seed cotton per acre	Increase in yield from phosphorus, lbs. per acre	pH value
1	Ruston fine sandy loam	4–0–4 4–8–4	3 6	337 663	326	6.6
*2	Ruston fine sandy loam	4–0–4 4–8–4	12 —	574 619	45	6.4
3	Olivier silt loam	4–0–4 4–8–4	10 15	1,076 1,186	110	5.6
4	Oktibbeha clay	4–0–4 4–8–4	9 18	543 613	70	5.6
5	Savannah very fine sandy loam	4–0–4 4–8–4	6 14	684 786	102	6.7
6	Savannah very fine sandy loam	4–0–4 4–8–4	38 48	1,333 1,341	7	7.5
7	Cahaba fine sandy loam	4–0–4 4–8–4	12 17	619 707	88	6.1
8	Grenada silt loam	4–0–4 4–8–4	15 29	1,318 1,352	34	7.2
9	Trinity fine sandy loam	4–0–4 4–8–4	60 85	707 733	25	8.4
10	Houston clay loam	4–0–4 4–8–4	16 —	553 563	10	7.5

*Two years results only.

and 400 pounds of 4–0–4 fertilizer for five years. The results show a great difference in the fertility of each soil type. One contained only 3 ppm available phosphorus while another contained 60 ppm in the 4–0–4 plat. Although the reaction of many of the soils was suitable for phosphorus fixation, the available P_2O_5 in every soil was higher in the 4–8–4 plat, which shows a definite residual effect from 160 pounds of P_2O_5 applied over a period of five years. The soils which were originally low in available P_2O_5 gave an excellent response to phosphate applications. Increasing the available P_2O_5 in Ruston fine sandy loam (No. 1) from 3 to 6 ppm increased the cotton yields from 337 to 663 pounds per acre, an increase of 326 pounds. Soils containing from 6 to 15 ppm available P_2O_5 also responded to phosphorus, but not nearly as much as the one containing less available P_2O_5. Phosphorus applied to another Ruston fine sandy loam, very similar to No. 1 but containing 12 ppm available P_2O_5, increased the yield only from 574 to 619 pounds per acre.

Phosphorus applied to Savannah very fine sandy loam (No. 5) increased the available phosphorus from 6 to 14 ppm and increased the cotton yield from 684 to 786 pounds per acre. Oktibbeha clay with only 9 ppm available P_2O_5 showed an increased cotton yield from 543 to 613 pounds per acre when the available P_2O_5 was raised to 18 ppm, and Olivier silt loam gave an increase from 1,076 to 1,186 pounds of seed cotton per acre when the available P_2O_5 was increased from 10 to 15 ppm. Increasing the available P_2O_5 in Cahaba fine sandy loam from 12 to 17 ppm increased the cotton yield from 619 to 707 pounds per acre; but soils with available phosphorus higher than 12 to 15 ppm failed to respond to phosphorus treatments. Increasing the available phosphorus in Grenada silt loam from 15 to 29 ppm only increased the yield of cotton from 1,318 to 1,352 pounds per acre, an insignificant increase. Savannah very fine sandy loam (No. 6), very similar in texture and structure to soil sample No. 5 but containing 38 ppm available phosphorus, failed to respond to the phosphate applications, although available P_2O_5 was increased to 48 ppm. Trinity fine sandy loam with 60 ppm available P_2O_5 only gave an increase from 707 to 733 pounds when the available phosphorus was increased to 85 ppm, and phosphate applications to Houston clay loam, containing only 16 ppm available P_2O_5, failed to increase the yield of cotton.

The data show that the soil which contained less than 6 ppm available phosphorus gave an excellent response to applied phosphate, and that soils with less than 15 ppm also responded to phosphorus until this level was reached. However, soils higher in available phosphorus than 15 ppm failed to respond to phosphate applications, although available phosphorus was greatly increased.

Scarseth and Tidmore (8), working with the Black Belt soils of Alabama, found a high degree of correlation between the growth of oats and available phosphorus by the Truog method. They found that soils with less than 30 pounds available P_2O_5 made very poor yields of oats without phosphate fertilization. The data in Tables 1 and 2 show an excellent correlation between crop yields and available P_2O_5 by the Truog method as long as the available P_2O_5 is less than

30 pounds per acre (15 ppm), and they indicate that cotton and sagrain will respond to phosphate applications only on soils containing less than 30 pounds available P_2O_5 per acre.

Probably the most widely used fertilizer for cotton is 4–8–4, and cotton tests show that 4–0–4 is almost as effective on soils with more than 15 ppm of available P_2O_5. In order for the plant to utilize its nutrients most efficiently, there must be a proper balance of the essential elements, and in southern soils 15 ppm available P_2O_5 is probably enough to maintain the proper balance between the limited nitrogen and potassium. Most southern soils are especially deficient in nitrogen, and if greater quantities were added more than 15 ppm available P_2O_5 would probably be required to maintain the balance.

Most southern soils, however, do not contain 30 pounds of available P_2O_5. Eighteen of the 22 soils studied contained less than 30 pounds of available P_2O_5, and most of these gave excellent response to phosphorus. It is very important, therefore, that phosphate fertilizer be applied to most southern soils. Phosphate-loving plants may even respond to phosphate treatments on soils high in available P_2O_5, but there is a limit to the amount of available P_2O_5 required for cotton and sagrain.

SUMMARY

Greenhouse studies were made by growing two crops of sagrain on 12 different soils, representing four samples of Susquehanna, Ruston, and Orangeburg fine sandy loams. The available P_2O_5 in each soil, which had received different phosphate treatments, was determined by the Truog method.

Susquehanna fine sandy loam, a poor soil in the field, gave as high yields in the greenhouse as Ruston and Orangeburg fine sandy loams, two excellent agricultural soils.

All of the soils studied in the greenhouse contained less than 6 ppm available P_2O_5, and 11 of the 12 responded to the first phosphate applications, but none responded to heavier applications. Sagrain yielded as well on soils with 10 ppm available P_2O_5 as on those with 40 ppm. Maximum yields were obtained on many soils with only 8 ppm (16 pounds per acre) available P_2O_5.

Field studies were made by growing cotton on 10 different soils for five years. Soil samples were obtained from the 4–8–4 and 4–0–4 treated plats and available P_2O_5 was determined by the Truog method.

The 10 soils varied greatly in their response to phosphorus. Those containing less than 6 ppm available P_2O_5 gave excellent response; those containing from 6 to 15 ppm gave some response; but those containing more than 15 ppm gave very little or no response to phosphorus, although available P_2O_5 was greatly increased by the phosphate application.

Cotton and sagrain failed to respond to phosphate applications on soils containing 15 ppm or more available P_2O_5, which indicates that under southern conditions crops do not require large quantities of phosphorus. Most southern soils do not contain 15 ppm available P_2O_5 and require phosphorus, but applications should not be made

without determining the available P_2O_5 present. It is believed that when nitrogen and potassium are limited and phosphorus fixation is at a minimum, phosphate recommendations for cotton and sorghum may be made on the following basis: Soils containing less than 6 ppm available P_2O_5 require liberal applications, those containing from 6 to 15 ppm require light applications, but those containing more than 15 ppm require very little or no phorphorus.

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SEED COLOR STUDIES IN BIENNIAL WHITE SWEET CLOVER, *MELILOTUS ALBA*[1]

MATTHEW FOWLDS[2]

SWEET clover is adapted to growth over a wide area. Its value as a forage and soil-improving crop is well recognized. New characters which modify the appearance, quality, or adaptation of the crop are of general interest to growers and plant breeders.

The varieties of sweet clover commonly grown have yellow seed. In certain varieties the seed coat may be mottled with a reddish purple pigment. Pale yellow seed is another color variation which the writer has occasionally found as a mixture in some lots of ordinary sweet clover seed. A single mature plant which produced green seed was discovered by the writer in 1933. This paper presents investigations with green seed, pale yellow seed, and hybrids between these forms and the ordinary yellow-seeded sweet clover.

REVIEW OF LITERATURE

Coe and Martin (3),[3] working with sweet clover seed, reported that a well-developed "light line" was formed in the outer region of the Malpighian layer just below the base of the cones. After soaking the seed in water containing stains, they found that the light line in hard seed was the region which prevented the absorption of water. In permeable seeds, canals were found to cross the light line thus forming passageways through which water entered the seed. In histological studies Stevenson (4) found that the cells were less closely packed in permeable areas and that penetration was by way of the middle lamella.

Stevenson (4) investigated the inheritance of mottling in *Melilotus alba*. The mottled condition of the seed coat was found to be dependent upon a single factor pair and was inherited as a dominant character when other factors were favorable for the development of pigment. The appearance of the seed coat was not always an accurate basis for classification since the seed may be potentially mottled and still show no trace of the pigment. The same plant may produce non-mottled seed and seed varying greatly in the degree of mottling. Since mottling occurs in the seed coat which is maternal tissue, the degree of mottling appears to be influenced by other factors which have not been determined. He states that the pigment involved in the mottling had all the general properties of anthocyanins and was located in the lower part of the Malpighian cells.

A type of sweet clover that differed widely from the common type has been described by Kirk (2). The plants were profusely branched from the crown and the stems were exceptionally fine. In a cross between the dwarf-branching type and tall sweet clover, Stevenson (4) found that the dwarf branching habit of growth was dependent for its expression upon a single factor difference. The common type was completely dominant to the dwarf-branching type.

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[2]Assistant Professor of Agronomy. The author acknowledges his indebtedness to Dr. S. P. Swenson, Associate Professor of Agronomy, for helpful criticisms in the preparation of the manuscript and for assistance with the statistical interpretations.

[3]Figures in parenthesis refer to "Literature Cited", p. 686.

MATERIALS

The material used in the study of green seed color was furnished by a single plant discovered in September 1933. This plant was found by a roadside at some distance from other sweet clover plants. A natural hybrid between the green-seeded form and a yellow-seeded plant was used in a study of the mode of inheritance of the green color.

Material for the study of pale yellow seed color was obtained from commercial lots of sweet clover. It was observed that a trace of pale yellow seed occurred in occasional lots of sweet clover seed examined for purity in the seed laboratory. The selections of pale yellow seed were made from different lots of sweet clover extending over a period of several years. A natural hybrid between pale yellow and yellow was used in the study of inheritance of the pale yellow color.

NATURE AND LOCATION OF COLOR IN THE SEED

The seed coat in sweet clover seed was found to be somewhat translucent. For this reason the embryo beneath the seed coat may influence the observed seed color. In order to determine the actual color in seed coat and embryo, it was necessary to remove the seed coat, but it was difficult to do this with dry seed. In this study scarified seed was placed upon moist blotting paper. After the seed had imbibed water the seed coat was easily removed and the color of each part could then be determined.

The normal color of well-matured sweet clover seed has been described as golden yellow. After removing the seed coat it was observed that seed coat and embryo of yellow seed were both yellow. Likewise in green seed both were green. The pale yellow seed was found to have a white seed coat and a yellow embryo.

The seed produced by a green female parent when pollinated by a yellow-seeded plant was pale green. The maternal seed coat of this F_1 seed was green as expected, but the embryo was yellow. The seed produced by this hybrid segregated for yellow and pale green. The pale green segregate was found to have a yellow seed coat and a green embryo, hence the color arrangement found in the pale green F_1 was reversed in the pale green F_2 segregate. The two forms of pale green seed could not be distinguished from each other by inspection, but they could readily be identified after the seed coat was removed and each part examined separately. The influence of the color combinations in seed coat and embryo upon the observed color of the seed is shown in Table 1.

TABLE 1.—*The location of color in seed coat and embryo in different genotypes of sweet clover seed and the relation of this arrangement to the observed seed color.*

Class	Seed coat	Embryo	Observed seed color	Remarks
1	Yellow (YY)	Yellow (YY)	Yellow	Common yellow seed
2	Yellow (Yy)	Yellow (YY)	Yellow	Homozygous yellow segregate
3	Yellow (Yy)	Yellow (Yy)	Yellow	Heterozygous yellow segregate
4	Green (yy)	Green (yy)	Green	Normal green seed
5	Yellow (Yy)	Green (yy)	Pale green	Homozygous green segrate
6	Green (yy)	Yellow (Yy)	Pale green	F_1 hybrid green × yellow
7	Yellow (YY)	Yellow (Yy)	Yellow	F_1 hybrid yellow × green*

*This class has not been observed.

Although coloration of seed coat and embryo may appear alike to the eye, the pigments show a different reaction to water at temperatures favorable for germination. Scarified seed of any type having a colored seed coat liberates a greenish yellow stain when placed upon a moist blotter. The white seed coats of pale yellow seed liberate no stain under similar conditions. Hard seed of any type fails to liberate the soluble pigment as long as water does not penetrate the seed coat. Excised embryos were placed upon moist blotting paper. These absorbed water and began to grow without liberating any stain. The results show that colored seed coats contain a soluble pigment and the white seed coats are free from such pigment.

According to Coe and Martin (3), the light line is the impermeable layer in sweet clover seed, while the outer layer of the seed coat is readily permeable to water. Since the embryo does not liberate any color, the soluble pigment should be located in the seed coat beneath the light line. Stevenson (4) has shown that the antocyanin pigment which gives rise to the mottled condition in certain types of sweet clover seed is located in the lower part of the Malpighian cells.

NATURAL CROSSING IN THE GREEN-SEEDED SELECTION

Green seed from the plant discovered in 1933 was sown in the greenhouse. The plants were grown under electric light during the winter and a crop of selfed seed was produced. After harvesting this seed the plants were transplanted to the field and, late in the season, one of them blossomed for the second time where it was exposed to cross-pollination with ordinary sweet clover. Progenies were grown from selfed seed and from open-pollinated seed in subsequent generations. The results from each line will be presented separately.

Selfed seed was sown in the greenhouse. About 100 seedlings from this seed were transplanted to a field plat in June 1934. When the seed from this plat was threshed in 1935, two shades of green were recognized but the significance of the color variation was not fully appreciated at the time. A part of the seed was sown on a small plat the following spring and the next crop harvested in 1937. The seed obtained from the 1937 crop was a mixture of green, pale green, and yellow. About 30% of the seed was found in the yellow class. A trace of mottling also occurred in the yellow and in the pale green portion of the seed.

After observing this segregation for seed color a sample of reserve seed from the 1935 crop was re-examined. The seed was separated into green and pale green classes. About 10% of the seed was found in the pale green class. The seed coats were removed from a few seeds in each class by the method previously described. The seed coats in each class of seed were found to be green, but the embryo in the pale green class was yellow. As shown in Table 1, this type of pale green seed is the F_1 hybrid produced by a green female parent.

Because volunteer sweet clover seedlings were killed by drought the previous season, only one source of pollen carrying the factor for yellow seed was in evidence at the time the green-seeded plants were in blossom. This source was a small plat containing a tall yellow-

seeded selection segregating for mottled seed. The mottled seed found in the hybrid portion of the 1937 crop is also a good indication that this plat was the true source of the foreign pollen.

Evidence that crossing took place in 1935 when the plants were in blossom was also shown by an important plant character. The green-seeded plants grown in 1935 were of medium height and produced numerous leafy stems. This dwarf branching growth habit resembles the habit described by Kirk (2) for the Alpha variety. The next crop grown in 1937 from the 1935 seed was a mixture of tall and dwarf plants. Stevenson (4) found that the common type of growth is completely dominant to the dwarf type. The yellow and the pale green seeds which were found in the 1937 crop were produced by these tall hybrid plants.

Although the hybrids comprised about 10% of the population, they produced approximately 40% of the seed harvested from the plat. This difference in seed production per plant is due in part to the difference in size of plant and to the natural tendency of tall plants to overshadow the dwarf ones growing near them. The results show that sweet clover variteies intercross readily when grown near each other. If sweet clover selections are to be kept pure, it will apparently be necessary to have the seed plat well isolated from other varieties.

MOTTLING IN THE GREEN-SEEDED SELECTION

A number of the mottled pale green seed which were found in the 1937 crop were separated for examination. The seed coat was found to be yellow and the embryo green; hence these must have been pale green segregates from the tall hybrid plants which were found in that crop. The mottling therefore must have developed in the yellow seed coat in conjunction with the yellow color.

Some of the mottled pale green seeds were sown in the greenhouse in October 1937 and plants grown during the winter. The plants produced normal green seed as expected from this genotype. All of the seed produced by one plant was distinctly mottled. Another plant produced seed without a trace of mottling. The others were intermediate in type of mottling. In this seed the pigment for mottling has developed in the green seed coat in conjunction with the green color. Stevenson (4) has studied the inheritance of mottling in a variety having yellow seed. From the limited observations in this experiment, mottling appears to follow the same tendencies in green seed that have been determined for it in yellow seed.

INHERITANCE OF THE GREEN SEED COLOR

The open-pollinated green seed produced by a single plant in 1934 was sown in the greenhouse. The plants were grown during the winter but they failed to blossom until the following summer. When the seed was mature, it was found that one plant was a hybrid producing yellow and pale green seed. The seed was separated into color classes. The yellow class contained 1,210 and the pale green class 458 seeds. The segregation was tested for goodness of fit to a 3:1 ratio by means

of the X^2 distribution and a X^2 of 5.374 was obtained. For one degree of freedom, this corresponds to a P value of between 0.01 and 0.02 in Fisher's (1) table. A deviation as great as the observed could be expected in 1 to 2% of the trials on the basis of random sampling. Although beyond the limit usually accepted as significant, the results indicate a 3:1 ratio.

An F_2 progeny was grown from each class of seed. The seed was sown in the greenhouse and the plants were transplanted to the field in June, 1936. The plants grown from pale green seed were set adjacent to a plat of yellow-seeded sweet clover. The plants grown from yellow seed were set in a single row on the border of a soybean plat and were spaced about 1 foot apart. The plants were all grown to maturity without protection from pollinating insects.

When the plants reached a suitable stage of maturity in 1937, the individual plants were cut, tied into bundles, and placed on the ground to dry. The seed was threshed by hand, placed in envelopes and removed to the laboratory to be cleaned and graded previous to classification.

The plat grown from pale green seed contained 31 plants. Since the plants were exposed to cross-pollination the new seed crop was mixed to some extent with pale green F_1 hybrid seed. Disregarding this hybrid seed, all of the plants bred true for green seed color. The pale green type of seed from which the plants were grown has not appeared in the progeny. This class of seed is therefore only a transitional stage in hybrids between green and yellow. The results show that the green color is recessive to yellow.

In the plat grown from yellow seed, several stunted plants failed to produce seed and were discarded. Eighty-four plants were available for classification. Of these, 46 segregated for yellow and pale green seed and 38 bred true for the yellow color. On the basis of a 2:1 ratio, the expected numbers were 56 and 28, respectively.

A random sample of seed was taken from each segregating population. Discolored and broken seeds were removed from the sample and discarded. The sample was then separated into yellow and pale green classes. The number of seed in each class was determined and the X^2 value for each population on the basis of a 3:1 ratio was calculated. The results are presented in Table 2.

Inspection of the data recorded in Table 2 shows that 31 progenies have a X^2 value under 3.841. This is designated as the 5% point in Fisher's table. Nine additional progenies lie within the 1% point. Six progenies lie beyond the 1% point and these indicate a wide departure from the expected values. From the merged data a X^2 of .8187 was obtained. The small value of this X^2 shows that the plus and minus variations have nearly cancelled each other. The data in Table 2 also show that one progeny is a perfect fit, 21 progenies have an excess of yellow, and 24 an excess of pale green. This type of distribution indicates that there is no persisting bias in favor of one class over the other.

TABLE 2.—*Classification of yellow and pale green seed in 46 segregating F_2 progenies from a natural cross, green × yellow, and the X^2 value for each progeny on the basis of a 3:1 ratio.*

Yellow seed	Pale green seed	X^2	Yellow seed	Pale green seed	X^2
524	225	10.175	371	127	0.066
667	189	3.894	548	168	0.901
650	252	4.152	617	184	1.758
620	209	0.019	630	170	6.000
587	236	5.929	623	221	0.631
602	213	0.559	679	278	8.368
634	192	1.359	746	257	0.207
604	237	4.537	786	287	1.747
595	242	6.834	639	171	6.533
757	281	2.375	732	252	0.195
395	93	9.191	454	199	10.438
607	185	1.138	802	219	6.864
548	199	1.071	561	186	0.004
589	165	3.906	572	199	0.270
568	177	0.612	567	182	0.196
560	165	1.942	646	242	2.402
697	267	3.739	637	206	0.142
573	183	0.253	283	81	1.465
573	180	0.482	202	75	0.636
359	135	1.427	344	134	2.345
617	177	3.104	225	84	0.786
815	224	6.560	380	157	5.140
393	118	0.992	207	69	0.000
Totals			25,785	8,692	0.8187

Another test for goodness of fit was made by comparing the observed distribution of X^2 values with the expected frequencies. These data are shown in Table 3.

TABLE 3.—*Test of agreement of the observed distribution of X^2 values with expected frequencies in 46 segregating F_2 progenies.*

X^2	P	C	O	O–C	$(O-C)^2$	$\frac{(O-C)^2}{C}$
0.0000	1.00	0.46	1			
0.0002	0.99	0.46				
0.0006	0.98	1.38	2	−2.60	6.76	1.470
0.0039	0.95	2.30	1			
0.0158	0.90	4.60	1	−3.60	12.96	2.817
0.0642	0.80	4.60	2	−2.60	6.76	1.470
0.148	0.70	9.20	5	−4.20	17.64	1.917
0.455	0.50	9.20	9	−0.20	0.04	0.004
1.074	0.30	4.60	4	−0.60	0.36	0.078
1.642	0.20	4.60	6	1.40	1.96	0.426
2.706	0.10	2.30	2			
3.841	0.05	1.38	5			
5.412	0.02	0.46	4 17	12.40	153.76	33.426
6.635	0.01	0.46	6			

$X^2 = 41.608$

From the data recorded in Table 3, a X^2 of 41.608 was obtained. For six degrees of freedom the corresponding P value is very small,

hence a deviation as great as this would not be expected on the basis of random sampling. The small value of P indicates a significant departure from the expected distribution on the basis of a 3:1 ratio. The big disturbing factor is the group of 17 progenies having high X^2 values. The other 29 progenies show a reasonably close fit to the expected distribution.

It is desirable in this connection to re-examine the material and the method of handling it in order to find if possible any disturbing factors which would explain this deviation. In several progenies difficulty was experienced in classifying seed of uneven maturity. Immature yellow seed which failed to develop beyond the green stage could not be distinguished with certainty from the green genotype. Errors in classifying samples of this type will result in high X^2 values.

Previous experience has shown that extensive crossing will occur between different types of sweet clover. Thirty-eight plants producing yellow seed were growing in the same plat with the segregating plants. These would increase the amount of available pollen carrying the factor for yellow seed. Two other plats of sweet clover, one green-seeded and one yellow-seeded, were growing nearby. Perhaps the available pollen was about equally divided between the two types, but the manner of its distribution to individual progenies by insect carriers is not known.

When due allowance is made for the disturbing factors in connection with pollination and for errors in sampling and in classifying the seed, it is thought that the evidence against the assumption of a 3:1 ratio is not convincing. Modifying factors which have not been determined in this study may account for part of the deviation from expected numbers. Observations made upon well-matured seed from selfed plants and data from the next generation would be desirable before reaching final conclusions.

INHERITANCE OF THE PALE YELLOW SEED COLOR

Pale yellow seed selected from commercial lots of sweet clover were sown in the field at different times as seed from this source became available. Plants grown from the selected pale yellow seed usually produced a seed crop of the ordinary yellow color, but an occasional plant was found that produced pale yellow seed. Since the original plants producing the pale yellow seed were grown among ordinary sweet clover plants, extensive cross-pollination was to be expected. Natural crossing would account for the small number of true breeding plants when these are grown from this source of seed.

In October 1933, pale yellow seed from a selected plant was sown in the greenhouse. The plants were grown under electric light and selfed seeds were matured during the winter. This seed was found to come true for the pale yellow color. A part of the seed was used to grow another generation in the greenhouse. From the plants continued in the greenhouse where crossing with other types was prevented, a true breeding line was readily established. A part of the selfed seed was also sown in the field. Whenever a new generation was grown from seed which matured in the field, only a small portion of the plants were found to produce seed of the pale yellow color.

A field-grown seedling was removed to the greenhouse in November 1936 and a crop of selfed seed was produced the following spring. The seed was found to be the ordinary yellow color. Evidently this plant was grown from a cross-pollinated seed. Some of the selfed seed was sown in a field row in May 1937. In an effort to obtain selfed seed, cloth bags were placed over branches on a number of plants when they were ready to blossom in 1938. Seed was obtained from nine plants. Of these, seven produced yellow seed and two produced pale yellow seed. Definite conclusions on the mode of inheritance should not be based on such a small number of plants, but the results suggest a 3:1 ratio. The pale yellow color was recessive to yellow.

In February 1938, a green-seeded plant was pollinated with pollen from a plant of the pale yellow type. Both of the parents were selected from selfed lines. The contrasting characters entering this cross were green vs. yellow embryo and green vs. white seed coat color. Hybrid seedlings were grown in the field during the summer and nine of the plants were removed to the greenhouse in November. Selfed seed was obtained from these in March 1939. The seed produced by this F_1 hybrid segregated for green and yellow embryo color as expected, but the seed coat was yellow. The results indicate that complementary factors are necessary for the expression of color in the seed coat. Perhaps the pale yellow type carries the recessive allelomorph of a basic factor for the production of seed coat pigment and a dominant factor for the determination of yellow color. Data from later generations will be required before the mode of inheritance can be fully determined.

SUMMARY

The seed coat in sweet clover seed is usually somewhat translucent. Because of this characteristic, color in the embryo may exert an influence upon the observed seed color.

Two forms of sweet clover, each distinguished by its seed color, have been described. In one form the seed coat and embryo are both green; in the other the seed coat is white and the embryo is yellow.

A pale green seed color which is represented by two distinct forms has been observed in a hybrid between green and yellow. These forms of pale green seed failed to breed true in the next generation.

A mottled condition in the seed coat of a yellow-seeded variety has previously been investigated. In a hybrid between yellow-mottled and green, a segregate has been found which has the mottled condition combined with a green seed coat.

The green seed color is inherited as a recessive to yellow and its determination appears to be dependent upon one main factor pair. The pale yellow seed color is also recessive to yellow.

In a cross between the factors for green seed coat and the white seed coat of pale yellow seed, the F_1 hybrid produced seed with a yellow seed coat. The expression of color in the seed coat appears to be dependent upon complementary factors.

Cross-pollination has occurred freely between the different varieties observed in this study. The crop of seed harvested from a small plat of green-seeded plants showed 10% of cross-pollination when

grown at a distance of 200 feet from a small group of yellow-seeded plants. If sweet clover selections are to be kept pure, the seed plat should be well isolated from other varieties.

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INFLUENCE OF LOW TEMPERATURE TREATMENTS ON THE GERMINATION OF SEEDS OF SWEET CLOVER AND SMOOTH VETCH[1]

L. E. DUNN[2]

GERMINATION percentages of sweet clover (*Melilotus alba* Desr.) and of smooth vetch (*Vicia villosa* Roth.) seed samples are reduced more or less by the presence of hard seeds, that is, seeds with coats impermeable to water. The hard seed content of sweet clover seed samples grown in western Oregon is often more than 45%, while that of smooth vetch seed samples is often more than 15%. Experiments were designed to find the influence of various low temperature treatments on the softening of hard seeds and on the germination of seed samples of sweet clover and smooth vetch.

REVIEW OF LITERATURE

A number of workers, including Harrington (1),[3] Helgeson (3), Jones (4), Leggatt (5), Lute (6), Midgley (7), Schmidt (9), and Whitcomb (10), have studied the influence of various storage conditions and storage in the soil on the softening of hard seeds of cultivat d legumes. The results indicate that when seedings are made in the spring nearly all hard seeds of alfalfa and hairy vetch will germinate and produce plants during the first season. The majority of the hard seeds of red clover and sweet clover will not germinate until the second season after the seeds have passed the winter in the soil. In case of red clover many of the hard seeds which become permeable during the winter do not produce plants because of being killed by the freezing weather of winter. Hard seeds of alfalfa and hairy vetch do not stand freezing readily after they have become permeable. Freezing weather is quite effective in the softening of hard seeds especially when the seeds are moist as they are in the soil.

Harrington (2) and Morinaga (8) have conducted experiments which show that the germination of some seeds are favored by favorable temperature alternations. Seeds of Bermuda grass, Canada bluegrass, cat-tail, Kentucky bluegrass, and orchard grass are examples of seeds favored by alternating temperatures.

As a result of these investigations, it was believed that a low temperature treatment might be found which would cause seed samples to give higher germination percentages than samples which had been stored dry at room temperature.

MATERIALS AND METHODS

Samples of locally grown sweet clover and smooth vetch seed were selected for carrying out the experiments. The various samples were given moist and dry treatments under the following storage conditions: (a) Room temperature aver-

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[3]Figures in parenthesis refer to "Literature Cited", p. 694.

age 22° C, ranging from 17° to 27°; (b) 5° C in a low temperature storage room, with a range from 2° to 10° C; (c) −10° C in a low temperature storage room, with a range from −8° to −12° C; (d) −10° C for 1 week followed by a continuous storage at 5° C; (e) alternation −10° C 1 week, 5° C 1 week; and (f) alternation −10° C 1 week, 22° C 1 week.

Storage periods ranged from 1 to 10 months. Following a treatment period for a sample, dead seeds and seeds which had produced radicles more than 1 cm in length during storage were discarded. For sweet clover, these seeds were removed by placing the treated sample in a beaker of water and decanting them off. The remainder of the sample was tested for germination.

Germination conditions consisted of holding the seeds on moist paper toweling in Petri dishes at room temperature. The period of a germination test was 14 days. After the first 7 days those seeds which had germinated were counted and removed. In case of sweet clover, seeds which had produced radicles with root hairs, elongated hypocotyls, and green cotyledonary leaves were considered to have germinated. In case of smooth vetch, seeds which had produced radicles with root hairs and plumules with green leaves were considered to have germinated. Hard seeds included seeds which had not swollen and which had not germinated during the germination test. Germination and hard seed percentages were based on the original number of seeds in a sample as 100%. In moist treatments where freezing temperatures were used, the envelopes with their samples were placed in water for 30 minutes and then allowed to drain just before storage. The seeds did not appear to be swollen at the beginning of the low temperature storage.

In case of moist treatments 1 and 6, where a temperature of 22° C was used either part or all of the time, a single sample of 1,000 seeds was used for each treatment and for all periods of time within that treatment. The samples were held on moist blotters in Petri dishes. In case of treatment 1 in which the seeds were kept continuously at 22° C, the dish was opened once each week and the germinated seeds were counted and removed. For treatment 6 in which the sample was held at 22° C every other week, germinated and dead seeds were counted and removed at the close of the 22° C interval. For dry treatments 1 and 6, samples were held in paper toweling envelopes.

In one of the experiments with smooth vetch, hard seeds were used for treatments 1 to 6, inclusive. These seeds were selected by picking the impermeable black seeds from seeds of the original lot which had been soaked for 30 hours at room temperature. During this period of soaking, permeable seeds swelled to more than twice their normal size and turned from black to a light or yellow brown color. At the close of a treatment for a sample, it was placed under germination conditions for 14 days. Seeds which had become permeable were recorded. In all cases hard seeds which had become permeable germinated normally when they were not frozen after taking up water.

EXPERIMENTAL RESULTS

RESULTS WITH SWEET CLOVER

The various treatments and the results are given in Tables 1 and 2. In all cases moist storage treatments were harmful to germination. Similar dry storage treatments had no influence on germination. The various moist and dry storage treatments were observed to have no significant influence on the softening of hard seeds.

TABLE I.—*Influence of various moist storage treatments on the germination and the softening of seeds of sweet clover.*

Period of treatment	Treatments†											
	No. 1, 22° C		No. 2, 5° C		No. 3, −10° C		No. 4, −10° C 1 week; 5° C continuous		No. 5, −10° C 1 week; 5° C 1 week		No. 6, −10° C 1 week; 22° C 1 week	
	Germination, %	Hard seed, %	Germination, %	Hard seed, %	Germination, %	Hard seed, %	Germination, %	Hard seed, %	Germination, %	Hard tion, %	Germination, %	Hard seed, %
Lot A												
0 (check)	45	51	—	—	—	—	—	—	—	—	—	—
1 week	46	50	45	55	57	41	—	—	—	—	—	—
2 weeks	0	50	20	52	54	44	44	48	40	53	2	55
1 month	0	50	18	36	41	55	14	34	12	50	3	51
2 months	3	47	0	32	12	51	0	27	4	50	1	44
4 months	1	46	0	33	24	44	2	26	3	51	0	44
6 months	2	42	1	27	4	41	0	23	0	44	0	41
Lot B												
0 (check)	37	62	—	—	—	—	—	—	—	—	—	—
2 weeks	1	60	36	62	43	56	41	64	38	61	0	64
1 month	0	60	1	63	32	61	2	62	3	58	1	63
2 months	0	59	0	58	24	63	1	62	2	58	0	63
4 months	0	57	0	54	20	57	0	59	0	57	1	62
6 months	0	54	0	62	8	54	0	61	1	52	1	61
8 months	0	53	1	53	0	46	0	53	0	51	0	60
10 months	0	53	0	62	0	55	0	51	0	60	0	59

*As a check against moist storage, seed samples were given similar treatments under dry storage conditions. In all cases the storage treatment had no influence on the percentage germination and the softening of hard seeds.

†In case of treatments 1 and 6, samples of 1,000 seeds each were used. For all other treatments samples of 300 seeds each were used.

TABLE 2.—*Influence of various storage conditions on the germination and softening of seeds of sweet clover.*

Period of treatment	Treatments											
	22° C, dry storage, samples of 300 seeds each		22° C, moist storage in Petri dishes, samples of 1,000 seeds each		5° C, dry storage, samples of 300 seeds each		5° C, moist storage in open paper towels, samples of 300 seeds each		5° C, moist storage in Petri dishes, samples of 300 seeds each		5° C, moist stoarge in open paper towels, samples of 3,000 seeds each	
	Germination, %	Hard seed, %	Germination, %	Hard seed, %	Germination, %	Hard seed, %	Germination, %	Hard seed, %	Germination, %	Hard seed, %	Germination, %	Hard seed, %
Lot A, Threshed Seed from Western Oregon, Seed 1 Year in Age												
0 (check)	54	42	—	—	—	—	—	—	—	—	—	—
1 month	46	50	0	42	47	47	1	42	1	44	0	49
2 months	52	48	0	42	46	48	0	47	0	45	0	47
4 months	43	41	0	41	51	44	0	43	0	47	0	46
6 months	52	46	0	40	55	44	0	43	0	45	0	44
8 months	58	42	0	40	42	48	0	42	—	—	0	45
10 months	46	53	0	40	46	51	0	47	—	—	0	41
Lot B, Threshed Seed from Western Oregon												
0 (check)	37	62	—	—	—	—	—	—	—	—	—	—
1 month	38	62	0	60	33	65	1	63	1	61	0	57
2 months	38	59	0	59	32	67	0	58	1	67	0	61
4 months	33	65	0	57	44	56	0	54	0	46	0	55
6 months	41	57	0	54	35	64	0	62	0	49	0	54
8 months	37	61	0	53	34	64	0	53	—	—	0	61
10 months	37	63	0	53	37	62	0	62	—	—	0	50
Lot C, Hand-hulled Seed from Western Oregon												
0 (check)	9	90	—	—	—	—	—	—	—	—	—	—
1 month	8	92	1	88	11	89	0	88	—	—	—	—
2 months	11	89	0	87	12	87	0	84	—	—	—	—
4 months	9	91	0	86	12	88	0	77	—	—	—	—
6 months	10	89	0	86	14	86	0	85	—	—	—	—
8 months	12	88	0	86	12	87	0	75	—	—	—	—
10 months	8	91	0	86	10	90	0	79	—	—	—	—

In the moist treatments many permeable seeds germinated in storage, and very few hard seeds became permeable. Therefore, the tests which followed the storage treatments gave very low germination percentages. In moist storage at 22° C, permeable seeds germinated within the first week. After intervals of 1 and 2 months in moist storage at 5° C, permeable seeds had produced radicles of approximately 1 and 2 cm in length, respectively. After periods of 4 months nearly all of the radicles were dead or partially decayed. In case of samples of 3,000 seeds each which were held in moist storage at 5° C, the seeds had weak radicles after 1 and 2 month intervals. For intervals longer than this nearly all radicles were dead. For these treatments above freezing, the small number of hard seeds which had become permeable produced healthy radicles and hypocotyls.

After samples were removed from the −10° C storage treatment, it was observed that permeable seeds were swollen. These samples gave low germination percentages. Apparently the permeable seeds had taken up enough water at the beginning of storage to be injured to some extent by freezing. Hard seeds were not injured by freezing.

At the beginning of the experiments, it was believed that under moist storage slightly above freezing enough water may enter some of the hard seeds to permit a normal slow growth of their embryos at this low temperature. The growing embryos in turn may finally injure the surrounding seed coats so that enough water could enter to permit a normal germination at 22° C. No results were obtained to support this concept.

RESULTS WITH SMOOTH VETCH

The results reported in Table 3 show that all moist storage treatments were harmful to the germination of seed samples of smooth vetch. Dry storage of the seed samples under the same treatments had no influence on germination. In case of moist storage at 22° C, permeable seeds germinated during the first week. In case of moist storage at 5° C, permeable seeds produced radicles over 1 cm in length in periods ranging from 2 to 4 weeks. Since seeds which had produced radicles more than 1 cm in length in storage were not counted as part of the germination of samples, germination percentages for the moist treated samples are very low. In case of the moist storage at −10° C, permeable seeds did not appear to be swollen at the time they were placed at this temperature. When these samples were removed and placed under germination conditions, the permeable seeds swelled to a marked extent and then decayed. Apparently enough water had entered the seeds previous to storage so that they were killed by the freezing temperature. Those seeds which germinated after the freezing periods probably were hard seeds which had become permeable in storage.

The moist storage treatments given in Table 3 appeared to cause some softening of hard seeds. The results given in Table 4 show that all the moist treatments were effective in causing a softening of hard seeds. There were marked variations in the impermeability of the hard seeds. In case of moist storage at 22° C, some of the hard seeds became permeable within 1 month, while others were still imperme-

TABLE 3.—*Influence of various storage treatments on the germination and the softening of seeds of smooth vetch.*

Periods of treatment	Treatment*					
	No. 1, 22° C		No. 2, 5° C		No. 3, −10° C	
	Germination %	Hard seed %	Germination %	Hard seed %	Germination %	Hard seed %
	Moist Storage in Paper Towels					
0	82	15	—	—	—	—
2 weeks	4	11	27	18	8	17
1 month	0	11	2	16	1	16
2 months	1	10	0	18	2	12
4 months	1	10	1	15	1	13
6 months	1	10	2	13	2	10
	Dry Storage in Paper Towels					
0	82	15	—	—	—	—
2 weeks	78	17	78	16	80	17
1 month	80	17	75	16	80	16
2 months	75	20	84	15	81	17
4 months	84	14	83	12	81	16
6 months	85	13	85	10	78	16

*In case of treatment 1 in moist storage, a single sample of 1,000 seeds was used for all treatment periods. For treatments 2 and 3 a sample of 300 seeds each was provided for each period.

able after 6 months. When hard seeds became permeable under these conditions, they first swelled and turned to a lighter color and then germinated. With the possible exception of moist storage at 5° C, moist storage at room temperature was as effective as any other treatment in causing a softening of hard seeds.

TABLE 4.—*Influence of various moist storage treatments on the softening of hard seeds of smooth vetch.*

Treatments	Periods of treatments in moist towels and percentages of hard seeds which became permeable after*					
	0	2 weeks	1 month	2 months	4 months	6 months
No. 1, 22° C	0	32	51	54	63	68
No. 2, 5° C	0	—	41	52	71	96
No. 3, −10° C	0	—	39	51	64	82
No. 4, −10° C 1 week and then 5° C continuous	0	—	64	65	72	95
No. 5, alternation −10° C 1 week; 5° C 1 week	0	—	36	62	70	78
No. 6, alternation −10° C 1 week; 22° C 1 week	0	24	62	57	72	83

*For treatment 1, a sample of 200 hard seeds was used for all periods. This was because the sample did not have to be removed from its regular storage treatment for germination conditions to be provided. Hard seeds counts for a given period were taken 2 weeks after the close of the period so that results would be consistent with counts for other treatments. For all other treatments, a sample of 200 hard seeds was provided for each period.

An initial freezing period of −10° C for 1 week, treatment 4, appeared to hasten the softening of a portion of the hard seeds when held moist at 5° C. However, by comparison with treatment 2, the initial freezing did not appear to influence the total number of hard seeds which had become permeable after 4 months storage.

In case of the −10° C moist storage, hard seeds were soaked in water 30 minutes just previous to the low temperature storage. The hard seeds did not take up enough moisture to be injured by freezing. Seeds which had become permeable at −10° C germinated normally when germination conditions were provided. In case of the temperature alternations, seeds which had become permable and which had swollen at the higher temperature were killed by the freezing temperature.

After 6 months moist storage under the various conditions only approximately 20% of the original seeds were still impermeable in selected 200 hard seed samples. These experiments would indicate that probably the majority of the hard seeds of smooth vetch would germinate and produce plants the first 2 or 3 months after planting. Probably only a very small percentage of the hard seeds would be left in the soil a year after planting.

SUMMARY

A number of experiments were conducted with locally-grown seed samples of sweet clover and smooth vetch to find the influence of various low temperature treatments and alternating temperatures on the softening of hard seeds and on the germination of seed samples. The various treatments consisted of moist and dry storage of seed samples under the following conditions: Room temperature; 5° C; −10° C; −10° C for 1 week followed by continuous storage at 5° C; alternations in weekly intervals between temperatures above and below freezing. Storage periods ranged from 1 to 10 months. At the close of a storage period for a sample, dead seeds and seed which had produced radicles more than 1 cm in length were discarded. The remainder of the sample was tested for germination.

No low temperature storage treatment was found which would cause seed samples of sweet clover and smooth vetch to give higher germination percentages than seed samples which had been stored dry at room temperature. Moist storage of the seed samples under the various low temperature and alternating temperature conditions was found to be harmful to germination. Permeable seeds produce radicles slowly in low temperature storage slightly above freezing. Permeable seeds which had absorbed enough water to be slightly swollen were injured or killed by freezing. Dry storage of seed samples under the same conditions was observed to have no significant influence on germination.

The various moist and dry storage treatments were observed to have no significant influence on the softening of hard seeds of sweet clover after storage periods ranging from 1 to 10 months. The various moist storage treatments were observed to be effective in the softening of hard seeds of smooth vetch. Samples of 200 hard seeds each were given the treatments. After 6 months storage only approxi-

mately 20% of the original hard seeds were still impermeable. In all cases hard seeds which had softened germinated normally when they were not frozen after taking up water. These results would indicate that probably the majority of hard seeds of smooth vetch would germinate and produce plants within the first 2 or 3 months after planting.

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PLOWING DATES AS THEY AFFECTED THE ABUNDANCE OF CORN ROOT APHIDS AT CLAYTON, ILLINOIS, 1929-1932[1]

J. H. BIGGER AND F. C. BAUER[2]

FOR many years the sole cultural practice recommended for the control of the corn root aphid, *Anuraphis maidi-radicis* Forbes, has been early plowing followed by repeated frequent discing of the soil to prevent re-establishment of the nests of the cornfield ant, *Lasius niger americanus* Emery, and growth of weeds to furnish food for the aphids prior to corn planting.

This recommendation probably originated with the extensive report on this insect by Dr. Forbes[3] in 1892 when he said, ". . . we may seek to handle the ground in such a manner that there will be no sufficient start of vegetation to keep the lice alive."

It was further developed and given a background of fact as reported by Flint[4] in 1919, and is recognized as an entirely satisfactory means of preventing damage by this insect. The authors wish in no way to displace this means of control when it can be carried out. It is desired only to furnish for the use of other workers in this line certain data obtained in pursuing a long-time project on observation of the effect of certain cultural practices on the root-infesting insects of corn.

HISTORY OF PROJECT

For four years, 1929–32, one part of this project was maintained in cooperation with the Department of Agronomy of the University of Illinois on the soils experiment field at Clayton in western Illinois on well-drained brown silt loam. A rotation of corn, oats, red clover, and wheat was practiced on the major series of this field. In this rotation, a grain system and livestock system of farming were compared. In the grain system sweet clover was grown in the wheat as a catch crop. This was returned to the soil the next spring as a green manure previous to corn planting. Corn crop residues were also returned to the soil. In the livestock system animal manure equal to the total weight of the crops produced in the previous rotation was spread on the ground and plowed under for corn. In both groups the first crop of red clover was removed for hay. The second crop was also removed for hay in the livestock system, but this crop was plowed under in the grain system previous to wheat seeding. (A common practice in Illinois is to gather the second crop of red clover for seed.)

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[1]Part of Project 3.6 of the Illinois Natural History Survey. Received for publication April 27, 1939.

[2]Associate Entomologist, Illinois State Natural History Survey Division, and Chief in Soils Experiment Fields, Illinois Agricultural Experiment Station, Urbana, Ill., respectively.

[3]FORBES, S. A. 18th Rpt. Ill. State Ent., 1891–1892. (Page 66.)

[4]FLINT, W. P. Ill. Nat. Hist. Sur. Circ. 4. 1919.

GRAIN SYSTEM	LIVESTOCK SYSTEM
Late plow	Late plow
Early plow	Early plow

FIG. 1.—Diagram of arrangement of soils experiment field at Clayton, Ill.

Plowing for corn was done in such a way that each of these areas was plowed at two different dates, the plowing being done at the same time in each, as indicated in the diagram in Fig. 1. Approximately 1 acre is included in each of the four resulting areas.

The early plowing is done as soon as sweet clover has made sufficient growth to be killed by turning under. The late plowing is done approximately two weeks later and about a week previous to corn planting. The early plowed land is not worked further until after the second plowing is done when the entire series is double disced and harrowed just previous to corn planting. The term "early plowing" is here used only to indicate the difference between the two groups. These dates of plowing (Table 1) would not ordinarily be considered early in the section of the state in which the field is located.

TABLE 1.—*Record of dates of plowing and planting at Clayton, Ill., 1929–32.*

Year	Early plowing	Late plowing	Planted	Date recorded
1929	Apr. 19	May 9	May 17	June 20–21
1930	Apr. 8	Apr. 23	May 6	June 2–3
1931	Apr. 15	May 1	May 13	June 8
1932	Apr. 13	Apr. 27	May 5	May 27

It is recognized that the early plowed area is not handled according to recommendations for corn root aphid control, but this handling is in general agreement with common practice followed by farmers in this area. The infestation later shown is not to be considered that which would result if previous control recommendations were followed.

METHOD OF GATHERING DATA

Corn is planted on these plats during the first part of May and cultivated in the usual manner. When the plants have reached a height of 6 to 8 inches, representative groups are dug in each plat. Duplicate 100-hill samples are taken in different sections of the series. The plants are dug with a spade and the entire root system present at that time is exposed. Visible presence of the insects themselves is the only basis for record of infestation. The practice of plowing twice on the field has been discontinued. Further records are not obtainable, so the data are here offered following only four years' study.

RESULTS OBTAINED

From the start of taking records it was apparent that the practice of plowing in the first half of April and not working the ground until just prior to corn planting resulted in a heavier infestation than the practice of plowing a week prior to corn planting and thorough working of the soil in the meantime. These results were consistent for the four-year period when the records were obtainable as shown in Table 2.

TABLE 2.—*Infestation by corn root aphids under two different cultural practices.*

Cultural practice	Percentage of hills infested					
	1929	1930	1931	1932	Average	Composite average
Early Plowing						
Livestock system	49.7	21.5	—*	30.0	33.6	26.5
Grain system	32.1	13.0	2.5	30.0	19.4	
Late Plowing						
Livestock system	32.9	14.5	11.0	14.4	18.2	15.7
Grain system	23.9	11.0	1.5	16.3	13.2	

*Plats not included in 1931.

RECOMMENDATIONS

The authors hesitate to make any formal recommendation on the basis of the four years of work on only one series of plats, though duplicate records were obtained in each case. The fact that previous recommendations are entirely satisfactory when carefully followed is also considered. It is felt, however, that under certain conditions it can be recommended that plowing of the field be delayed until just prior to corn planting where corn root aphid control is the only factor to be considered.

This should not be used to replace previous recommendations where it is possible to follow them. It is recognized that this is not generally good farm practice and that early plowing should be generally considered superior. This practice is to be recommended only when and where corn root aphids are the only important problem and other means of control are not possible.

METHODS FOR DETERMINING THE PERCENTAGE OF SEEDS, STRIGS, STEMS, AND LEAVES IN COMMERCIAL HOPS[1]

C. G. MONROE AND D. D. HILL[2]

THE seeds, strigs (the rachis of the hop strobile), stems, and leaves in commercial hops add little to the brewing value. Brewers generally consider seedless hops to be superior to seeded hops as the seeds are believed to impart undesirable flavors and odors to the brewed beverages. All of these materials add useless weight to the hops.

Brewmasters and hop dealers have made it a practice to estimate roughly the amount of impurities in a given sample. If analyses are necessary, the stems and leaves can be picked from the sample and the percentage determined accurately. The stickiness of the lupulin which covers the base of the bracts of the hop cone and the enclosed seed makes accurate physical analysis of this factor difficult. Lupulin also interferes with accurate determination of strigs.

At the request of the Oregon hop industry, experiments were initiated by the Oregon Experiment Station to study the physical and chemical properties of commercial hops. In this study it was necessary to determine accurately the percentage of seeds in a given sample. A comprehensive review of the literature on the subject revealed only two methods that had been used to accomplish this objective.

Epstein and Hubbard[3] suggested a method in which the seeds were plucked from the cones by hand and the lupulin removed from the seeds by rubbing between the thumb and index finger. When the fingers became oily they were dipped in 50% alcohol and wiped clean. About 2 hours were required to determine the seed content. of a 10-gram sample, which, according to Epstein and Hubbard, was the smallest sample that would give representive results.

Rabak[4] offered a more practical method by which 20-gram samples were heated to 105° C for 6 hours to destroy the stickiness of the lupulin so that the hops could be threshed by pulverizing between the palms of the hands and the seeds then screened out. This method limits the output of a commercial laboratory to the capacity of its ovens.

MATERIALS AND METHODS

An experiment was set up for the purpose of developing a more practical method for arriving at seed percentages in hops. Three lots of hops appearing to

[1]Published as Technical Paper No. 312 with the approval of the Director of the Oregon Agricultural Experiment Station, Corvallis, Ore. Contribution of the Department of Farm Crops. Received for publication May 1, 1939.

[2]Graduate Assistant and Associate Agronomist, Farm Crops Department, Oregon State College, respectively.

[3]Epstein, S. S., and Hubbard, W. S., The American Brewer, June, 1936.

[4]RABAK, F. Relation of seeds, leaves, and stems to the quality of hops and malt beverages. Printed and distributed by Materials Improvement Committee, Master Brewers' Association of America, Clinton, Iowa.

vary in seed content were selected. Ten-gram samples from each of these lots were subjected to two types of treatments to destroy the lupulin. In one treatment the samples were exposed to various temperatures for 1 to 6 hours; in the other they were dipped in alcohol and then dried. From this experiment, the following methods were selected as the most promising: Heating at 105° C for 6 hours, heating at 115° C for 2 hours, and the alcohol-solvent method.

A second experiment was set up to determine the comparative accuracy of these three methods. From each of five different lots of commercial hops, three sets of five 20-gram samples were selected to be treated by each of the three methods. The samples were taken from hop bales and accurately weighed to 20 grams. All stems, leaves, and portions of leaves more than ¼ inch in diameter were picked out and weighed to 0.01 gram, and the percentage determined. In the first experiment it had been found that it was more practical to separate the stems and leaves before heating or dipping in alcohol, as the leaves were less likely to be broken and therefore more easily removed. The samples to be heated were placed in covered soil cans and heated in a thermostatically controlled electric oven in which the temperature would be controlled with an accuracy of ±2° C.

The individual samples for the alcohol-solvent method were placed on 2-foot squares of muslin or cheesecloth and immersed in a quart bowl of methyl alcohol for 1 minute. The excess alcohol was pressed by hand from the sample and retained for further use. Rubber-coated gloves were used to protect the operator's hands from the staining effect of the alcohol and lupulin.

The cloth containing the hops was next spread out to dry on a screen over a steam radiator. Breaking up the cones and stirring them occasionally speeded up the drying process. Twenty to 30 minutes were required for drying.

Identical methods of threshing were used for all treatments. The cones were pulverized between the palms of the hands, and the chaff separated from the seeds and strigs, or central stems of the cones, with a laboratory fanning mill. The seeds were readily separated by screening out the larger strigs, then placing the seeds and remaining strigs on an incline and manipulating in such a manner that the seeds rolled off while the irregularly shaped strigs do not. The seeds and strigs were weighed separately and their percentages by weight determined. The weight per 1,000 seeds was determined for each treatment.

EXPERIMENTAL RESULTS

Results of the preliminary trials are shown in Table 1. This experiment indicates that heating at higher temperatures for shorter periods of time is comparable to the 6-hour treatment at 105° C, and that the alcohol-solvent method compares favorably with the heat treatments. The variations in seed percentages, though small, indicated that the 10-gram samples were too small.

Individual percentages of seeds and strigs with averages for each sample and each treatment are shown in Table 2. The data obtained from all three methods show comparable results, although the percentage of error from the 2-hour heat treatment is slightly higher than from the other two methods.

For convenience, the averages from Table 2 are summarized in Table 3.

DISCUSSION

The percentage of probable error indicates the variations within each of the different methods, part of which is the result of variations

TABLE 1.—*Comparison of methods of seed determination in hops, preliminary trial.*

Treatment	Lot 45A		Lot 37		Lot 51	
	% seeds	Condition*	% seeds	Condition*	% seeds	Condition*
Heat, 105° C, 1 hr.	9.2	Slightly sticky	11.2	Slightly sticky	19.0	Sticky
Heat, 105° C, 2 hrs.	6.5	OK	11.8	OK	16.5	Slightly sticky
Heat, 105° C, 3 hrs.	7.6	OK	8.9	OK	16.1	Slightly sticky
Heat, 105° C, 4 hrs.	7.3	OK	12.0	OK	16.5	Slightly sticky
Heat, 105° C, 5 hrs.	7.4	OK	10.1	OK	17.0	OK
Heat, 105° C, 6 hrs.	7.1	OK, cones brown	11.1	OK	17.7	OK
Alcohol solvent....	8.3	OK	11.5	OK	17.2	OK
Alcohol solvent....	6.9	OK	11.1	OK	17.9	OK
Alcohol solvent....	7.0	OK	9.9	OK	17.5	OK
Alcohol solvent....	8.0	OK	11.5	OK	18.9	OK
Alcohol solvent....	6.8	OK	10.8	OK	18.2	OK
Average........	7.4		11.0		17.9	
P.E. ±†..........	0.254		0.287		0.203	
P.E. %..........	3.43		2.61		1.13	

Trials at Higher Temperatures with Lot 45A

No.	115° C, 2 hrs.		120° C, 2 hrs.		120° C, 1 hr.	
	% seeds	Condition	% seeds	Condition	% seeds	Condition
1...............	8.2	OK	8.6	OK, tobacco brown	8.1	Slightly sticky
2...............	7.2	OK	8.0	OK, tobacco brown	7.3	OK
3...............	8.8	OK	8.0	OK, tobacco brown	9.2	Slightly sticky

*Condition refers to the condition of the sample for threshing.
†Probable error computed by Peter's formula.

in sampling. The low percentage of error in all cases indicates that all of these methods are reasonably accurate.

Results of the heat trials indicate that the 2-hour method at 115° C is as accurate as the 6-hour method at 105° C. One advantage of the former is that it will enable a laboratory to analyze four times its oven capacity in an 8-hour day. Where oven space is the limiting factor, this is a decided advantage over the 6-hour method.

The alcohol-solvent method gave results comparable to those obtained from the heat treatments. The determination of strigs by

TABLE 2.—*Comparison of methods of seed determination in hops, final experiment.*

No.	Lot 27A		Lot 51A		Lot 44		Lot 49A		Lot 8A	
	% strigs	% seeds	% strigs	% seeds	% strigs	% seeds	% strigs	% seeds	% strigs	% seeds
Alcohol-Solvent Method										
1	8.6	4.0	8.5	7.7	8.0	8.6	8.9	15.0	7.6	19.7
2	7.3	3.9	9.9	7.9	8.0	9.0	8.9	15.4	8.5	20.8
3	7.4	4.1	10.2	8.4	8.3	8.1	9.2	15.5	8.4	20.3
4	8.7	4.1	9.7	7.8	7.4	10.3	9.0	15.5	8.9	20.0
5	8.3	3.8	10.2	8.1	7.9	10.1	9.6	16.3	7.7	21.3
Ave.	8.1	4.0	9.7	8.0	7.9	9.2	9.1	15.5	8.2	20.4
P. E. ±	0.237	0.042	0.203	0.093	0.093	0.330	0.093	0.118	0.194	0.211
P. E. %	2.93	1.05	2.09	1.16	1.18	3.59	1.02	0.76	2.37	1.03
Weight of 1,000 seeds, grams		3.92		4.23		3.64		4.10		3.27
Heat at 115° C for 2 Hours										
1	7.8	4.1	9.1	8.9	7.5	8.0	7.5	15.0	9.0	22.0
2	8.5	3.8	8.0	8.0	7.2	9.0	5.1	13.2	8.2	19.8
3	8.1	4.6	7.8	9.5	7.4	8.7	8.2	15.5	7.1	20.6
4	8.1	3.8	6.5	8.2	5.0	10.1	6.5	15.8	8.8	21.4
5	8.4	4.2	7.5	7.5	6.0	8.4	6.7	16.1	7.8	19.0
Ave.	8.2	4.1	7.8	8.4	6.6	8.8	6.8	15.1	8.2	20.6
P. E. ±	0.093	0.101	0.262	0.262	0.380	0.237	0.355	0.346	0.245	0.389
P. E. %	1.13	2.46	3.36	3.12	5.76	2.69	5.22	2.29	2.99	1.89
Weight of 1,000 seeds, grams		3.70		4.44		3.70		4.30		3.14
Heat at 105° C for 6 Hours										
1	7.1	4.0	9.2	8.1	5.0	8.3	5.6	13.3	7.5	20.6
2	6.7	3.8	7.2	8.0	4.8	8.4	7.0	13.2	7.4	19.7
3	8.2	4.4	8.6	8.2	5.3	9.5	7.4	13.6	7.1	19.4
4	8.3	4.8	8.0	7.4	6.6	9.4	6.1	13.7	7.4	19.0
5	8.0	3.9	8.4	8.1	7.5	8.5	7.2	14.2	7.0	19.9
Ave.	7.7	4.2	8.3	8.0	5.8	8.8	6.7	13.6	7.3	19.7
P. E. ±	0.253	0.144	0.228	0.084	0.406	0.211	0.270	0.118	0.076	0.177
P. E. %	3.28	3.43	2.75	1.05	7.00	2.40	4.03	0.87	1.04	0.90
Weight of 1,000 seeds, grams		3.93		4.36		3.74		4.08		3.36

TABLE 3.—*Comparison of the averages of the three methods, summary of Table 2.*

	Alcohol solvent			Heat, 115° C, 2 hrs.			Heat, 105° C, 6 hrs.		
	% by weight	% P.E.	Weight of 1,000 seeds, grams	% by weight	% P.E.	Weight of 1,000 seeds, grams	% by weight	% P.E.	Weight of 1,000 seeds, grams
Seeds	11.4	1.52	3.85	11.4	2.49	3.86	10.9	1.73	3.89
Strigs	8.6	1.92	—	7.5	3.69	—	7.2	3.62	—

this method appeared to be slightly more accurate, as indicated by a lower probable error. An important advantage of the method is that no oven is required and that the work can be done wherever facilities are available for drying. In the opinion of the senior author, who conducted most of the actual trials, samples treated with alcohol threshed more easily and were more satisfactory to handle. Heating appeared to cause parts of the bracts to adhere to the seeds, thus interfering in threshing.

The alcohol-solvent method was adopted by the Oregon Experiment Station. It was used on approximately 1,000 samples from more than 300 different lots of commercial hops and gave satisfactory results. Results were entirely satisfactory. Experience shows that one man can determine the percentages of stems, leaves, seeds, and strigs of 25 20-gram samples in one 8-hour day, using only 3 pints of methyl alcohol.

SUMMARY AND CONCLUSIONS

To determine accurately the percentage of seeds in commercial hops, the lupulin must be removed. Lupulin is the sticky, yellow material which adheres to the seeds and the bases of the bracts making accurate separation difficult.

The use of methyl alcohol used as a solvent appears to be the most satisfactory method of those tried. The short time and the small amount of equipment and materials required, the simplicity of the method, and its accuracy are definite advantages. This method is definitely more accurate for determining percentages of strigs than the heat methods, which tend to cause the strigs to become so brittle that they break and are lost in threshing.

Heating 2 hours at 115° C appears to be as satisfactory as heating 6 hours at 105° C.

Twenty-gram samples are easy to handle, and according to the probable errors obtained, they are sufficiently accurate to be dependable.

THE USE OF CROP RESIDUES FOR SOIL AND MOISTURE CONSERVATION[1]

F. L. DULEY AND J. C. RUSSEL[2]

METHODS of crop production in the Great Plains have been greatly improved during the last 40 years. There remains, however, much to be done from the standpoint of reducing the number of crop failures. The hazards encountered in Great Plains agriculture are due not so much to the fact that the total rainfall is low as to its uneven seasonal distribution, high summer temperatures, and frequent extended periods of drought. The fact that most of the precipitation comes during the warm season makes it difficult to get deep penetration of water into the soil because of excessive evaporation losses. The total loss of water by evaporation in the Great Plains may equal or exceed the amount used by the crop and may be two to four times as much as the water lost by runoff.

Any method for increasing the efficiency of Great Plains rainfall should include the possibilities for improving moisture conditions by reducing the rate and amount of evaporation of water from the soil surface. Although the losses due to runoff may be the more easily controlled, if some practical method could be devised that would reduce simultaneously the moisture losses from runoff and from evaporation, it would be a definite step toward maximum efficiency of rainfall utilization.

In the experiments herein reported an attempt is being made to utilize crop residues directly to increase the efficiency of rainfall for plant production in regions of low precipitation. Under the present system of harvesting most of the small grain and some sorghums with combines, much more crop residue than formerly is left on the land. Furthermore, these residues are spread quite evenly over the surface of the fields. It has long been known that debris of any sort on top of the ground will increase the intake of water and also reduce evaporation. Recent results obtained by Duley and Kelly (2)[3] through the artificial application of water have shown that the stubble and straw residue left by the combine is very effective in increasing the amount of infiltration that takes place during rains. Compared with cultivated bare soil, even a light covering of crop residue will greatly increase the amount of water entering the soil and will also reduce the evaporation loss of soil moisture. Erosion by either wind or water may be reduced to a minimum or practically eliminated where there is an appreciable amount of crop residue on top of the soil.

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[1]Contribution from the Soil Conservation Service, U. S. Dept. of Agriculture, and the Nebraska Agricultural Experiment Station, Lincoln, Nebr., cooperating. Published with approval of the Chief of Research, Soil Conseravtion Service, and the Director of the Nebraska Agricultural Experiment Station. Journal Series No. 232. Received for publication May 5, 1939.

[2]Senior Soil Conservationist and Cooperative Agent and Professor of Agronomy, University of Nebraska, respectively.

[3]Figures in parenthesis refer to "Literature Cited", p. 709.

UNCROPPED PLATS

In order to test the effect of crop residues on the amount of moisture that could be stored in uncropped land during the season, plats were started in the spring of 1938 with the treatments shown in Table 1. These plats were located at the Agronomy Farm, Lincoln, Nebraska, on a heavy subsoil Marshall silt loam with a slope of about 5%.

TABLE 1.—*The effect of straw and different tillage treatments on the storage of water in the soil.*

Plat No.	Treatment*	Rainfall conserved		Depth of water penetration, feet
		Surface inches	%	
1	Straw, 2 tons disked in	6.92	38.7	5
2	Land disked, no straw	3.49	19.5	4
3	Straw, 2 tons on the surface	9.72	54.3	6
4	Straw, 2 tons plowed in	6.12	34.2	5
5	Land plowed, no straw	3.71	20.7	4
6	Decayed straw, 2 tons plowed in	3.12	17.4	4
7	Basin listed	4.95	27.7	5

*A second application of straw was made to these plats on August 9, 1938.

Samples were taken to a depth of 6 feet on these plats April 23, May 24, July 14, August 9, and September 8. The samples were from four separate locations in each plat. They were taken in foot sections except the surface layer which was divided into two 6-inch sections. Weeds were kept down on the plats by hoeing except where the straw was on the surface. Here the cultivation was done by means of a broad duckfoot cultivator with sweeps 22 inches across which has been devised to cultivate the land and leave the crop residue on the surface. (See Figs. 1 and 2.)

The results from this phase of the work have been summarized in Table 1 by showing the total accumulation of moisture under different methods of fallow during the season between April 23 and September 8, 1938. During this time 17.9 inches of rain fell and the amount of moisture saved under each treatment is shown as percentage of total rainfall, in surface inches, and in depth of penetration of the water into the soil.

It will be noted from Table 1 that where straw was applied on the surface 54.3%, or 9.72 inches, of water was saved during the season. When this is compared with ordinary methods of clean fallow reported on plat 5, it will be seen that the moisture saved is more than two and one-half times that on the plowed land. The moisture saved on bare fallow is in line with results of other work done on some of the dry land experiment stations (1, 4). The moisture saved when the straw was disked in or plowed in was much more than on land plowed without straw, because a considerable amount of straw was left sticking out which protected the surface and reduced runoff. The moisture saved where the straw was plowed under was less than on land where the straw was on the surface or simply disked into the top soil.

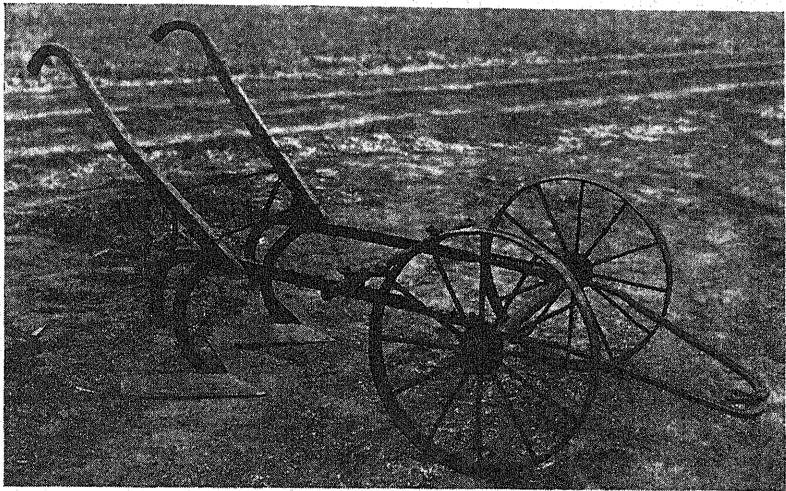

FIG. 1.—Broad sweep shovel for cultivating soil with crop residues on the surface. This tool will kill weeds, cultivate the soil, and leave the debris on top of the ground for protection against runoff, erosion, and evaporation. This type of shovel with a higher and more curved shank has been fitted to a tractor-drawn heavy-type, duckfoot cultivator and used successfully on combine-stubble land.

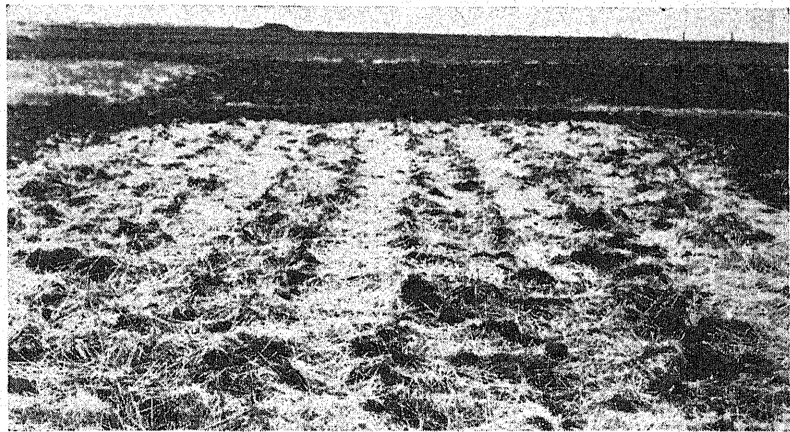

FIG. 2.—Straw-covered plat which has been cultivated with broad duckfoot cultivator. Note that the straw has been left evenly distributed over the surface.

It should be further noted that on plat 6, where the decayed organic matter was plowed under, there was no advantage so far as moisture conservation is concerned over plowing with no straw.

The results with basin listing are of particular interest because on this land there was no runoff, yet the amount of water conserved

during the season was only half the amount stored under straw. This emphasizes the fact that preventing runoff is not the full solution for the moisture problem in the Great Plains. On this plat the losses due to evaporation from the convoluted bare surface tended to offset the gains due to the prevention of runoff. The basin listing did, of course, prevent erosion, but this was also true where the straw treatments were used. The results indicate that in both the plats where straw was left on or near the surface, there was a decided saving of moisture over that on the basin listed land.

CONSERVING MOISTURE IN PREPARATION OF A WHEAT SEEDBED

In order to obtain further information on the effect of crop residues in moisture conservation and also to determine their effect on crop yields, experiments are being started in which use is being made of the residue from different crops in conserving moisture in the soil. A rotation of corn, oats, and wheat is being used in which the straw from the small grain crops and the corn stover will be returned and maintained on the surface for a time to aid in soil and moisture conservation. Following the oats crop in 1938 the straw was removed and in its place a weighed amount of wheat straw was returned amounting to 2 tons per acre. This was done on August 1, at which time soil moisture samples were taken and the treatments shown in Table 2 were applied to triplicate plats. During the period August 1 to September 21, the rainfall was 8.34 inches. In Table 2 is also given the amount of rainfall saved in surface inches and in percentage of the total rainfall, and also the depth of penetration of moisture into the soil.

TABLE 2.—*The effect of straw and different tillage treatments on the storage of water in stubble land being prepared for winter wheat, Aug. 1 to Sept. 21, 1938.*

Plat No.	Treatment	Rainfall conserved		Average depth of water penetration, feet
		Surface inches	%	
1	Straw, 2 tons on surface, land worked with one-way disk	4.16	49.9	2.7
2	Straw, 2 tons on surface, worked with sub-surface duck-foot cultivator	4.05	48.6	2.6
3	Straw, 2 tons, basin listed	3.80	45.6	2.8
4	Straw, 2 tons, plowed in	3.04	36.4	2.1
5	No straw, land plowed	1.87	22.4	1.6

It will be noted that where the straw was left on top or disked into the surface, almost half of the rainfall was held in the soil. The basin listing in this case stored 45.6% of the rainfall, which was more nearly equal to the amount saved by the straw treatments than was the case in the uncropped series reported in Table 1. Where the straw was plowed in, even though a certain amount of straw was not completely covered, the saving of moisture dropped to 36.4% and where

the straw was removed and the land plowed the amount of moisture saved was only 22.4%. On the land where the straw was on or near the surface water penetrated well into the third foot. This was also the case where the land was basin listed, but here the moisture was deeper under the furrows than under the ridges. Where the land was plowed, moisture was down only slightly below the 2-foot level and on the land plowed after the residue had been removed, water had reached only 1.6 feet. Work done on the dry-land experiment stations in the Great Plains has shown that the depth of penetration is of much importance for the following wheat crop (3). A distinct advantage has been gained both in total water saved and in depth of penetration where the crop residue has been left on the surface of the ground.

CROP RESIDUES ON CORN LAND

The idea of protecting the surface of the soil from runoff and evaporation and thus obtain a maximum conservation of water throughout a whole cropping system was extended to a series of corn experiments conducted during 1938. Wheat straw at rates of 2, 4, and 8 tons per acre was applied on the surface of the soil having a slope of about 5% that was to be planted to corn. Some of these rates are very high, and they were used mainly for the purpose of determining the maximum effects on moisture conservation and also for the purpose of determining whether such applications might have any detrimental effects on the growth of corn resulting from a reduction of the available nitrogen or other plant food material. In these tests the furrows for corn were made by means of disk furrow openers and the straw was applied by hand between the rows. When the corn was cultivated, the small ridge of soil thrown out in making the furrow was pulled back around the corn in order to free the row of weeds. The land between the rows was relatively clean and required very little cultivation. The cultivation that was finally given was by means of a heavy hoe drawn underneath the straw cutting only about an inch of soil. These straw-treated plats were compared with plowing and with basin listing. All of the plats were on the contour on an approximate 5% slope.

Results obtained in this first year's test should be considered only preliminary. In the first place, the 1938 season was unfavorable for corn in this part of Nebraska and grasshoppers did considerable damage. Methods of cultivation adapted to corn land with a considerable amount of debris on the surface have not yet been perfected. The total yield of air-dry fodder was low, but there were some differences which are of interest in connection with this whole idea of soil and moisture conservation by the more effective use of crop residues. Table 3 shows the treatments, which were carried out in quadruplicate, the yields of fodder, and the surface inches of water stored by these different treatments to a depth of 6 feet in excess of that stored by the check plats.

No measurements of runoff or erosion were made on these plats. It was observed, however, after different rains during the season that a considerable amount of runoff and erosion had taken place on the

TABLE 3.—*The effect of straw treatments on yields of corn fodder and storage of soil moisture, May 18 to Sept. 27, 1938.*

Plat No.	Treatment	Yields of air-dry fodder per acre, lbs.	Relative yields, %	Moisture storage due to treatments in excess of check, surface inches
1	Land plowed and planted with furrow openers	3,890	100	—
2	Basin listed	4,270	109	0.23
3	Straw, 2 tons per acre between rows	4,870	125	1.42
4	Straw, 4 tons per acre between rows	5,080	130	2.87
5	Straw, 8 tons per acre between rows	5,350	137	3.20

check plats. Soil had been carried across these plats and deposited in the first row of the straw-covered plat below. There was no evidence of either runoff or erosion on any of the mulched plats.

DISCUSSION OF RESULTS

While the results reported in this paper must necessarily be considered as preliminary in nature and are presented only as a progress report of this work, there are certain rather fundamental considerations regarding moisture conservation that seem to be indicated.

In the first place, leaving crop residues on the surface of the ground appears to be a very effective and practical method of conserving soil and soil moisture in the Great Plains. Used in this way they may be expected to have the following beneficial effects: (a) Greatly increase infiltration and thereby reduce the amount of runoff; (b) reduce evaporation from the surface soil; (c) reduce the amount of water erosion; and (d) reduce the amount of wind erosion.

It is also recognized that this organic debris left on the surface of the soil for an extended period may have many other physical, chemical, and biological effects, some of which may be favorable and some unfavorable to crop production, but no attempt will be made here to discuss any of these factors. The decayed part of the residue as well as a certain amount of undecomposed material would, of course, be gradually worked into the soil by whatever cultivation practice that may be used. This decayed organic matter incorporated with the soil may aid in the maintenance of fertility, but in these tests it had little effect on the storage of soil moisture.

These tests, along with much practical experience by farmers, would seem to emphasize the importance of continuous protection of land in the Great Plains, either by a growing crop or by the use of crop residues on the surface until another crop can be started.

The results reported in this paper indicate that for storing and conserving moisture in the soil, protecting the land with plant residues when available in sufficient quantity may be a much more efficient method than is the use of clean or "black" fallow now so generally

used throughout the regions of low rainfall. It must be remembered that a cultivated bare soil is the surface condition in which land is most likely to lose excessive amounts of water by runoff, permit the greatest loss by evaporation, and submit the soil to the greatest possible hazard from erosion by either wind or water.

When all these things are considered, it would seem that the proper utilization of crop residues on the surface of the soil may offer a simple and practical method for reducing runoff and erosion. By increasing infiltration and reducing evaporation losses a more efficient use may be made of the rainfall, which appears to be absolutely necessary for the maintenance of a stable and permanent agriculture in the Great Plains.

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THE BREEDING OF IMPROVED SELFED LINES OF CORN[1]

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COMMERCIAL and experiment station plant breeders are of the opinion that there will continue to be a rapid increase in the use of hybrid corn until the greater part of the field corn acreage in the United States is planted to hybrid varieties. The reasons for the rapid expansion of hybrid corn are rather well known. The primary cause is the greater efficiency of adapted hybrids in yield per acre, ability to withstand lodging, uniformity of maturity, disease resistance, and other important characters.

The explanation of hybrid vigor was placed on a Mendelian basis by Jones (7)[3] and the results of experiments by Richey and others (8, 9) have given some evidence that lends added support to this explanation. If the Mendelian explanation proves the correct one, it furnishes a genetical basis for the belief that improved inbred lines can be developed by the same plant breeding methods that have been so successfully applied to self-pollinated crop plants.

Most of the inbreds already used in commercial hybrids have been obtained by self pollination and selection from commercial varieties. All inbred lines of field corn now available are much less vigorous than the normal varieties from which they were selected. An inbred line may be far superior, however, to the commercial variety from which it was selected in some one character, such as ability to withstand lodging or disease resistance. The major difference in the breeding of improved selfed lines of corn from crosses between available inbreds and subsequent selection in self-pollinated lines and the breeding of improved varieties of self-pollinated plants is the necessity of controlling pollination in corn.

After a wide collection of selfed lines has been selected from normally pollinated adapted varieties and from other breeders, three rather specific methods of breeding are available in the development of improved inbreds. These are the pedigree method, backcrossing, and convergent improvement. Backcrossing and convergent improvement are being used extensively by many corn breeders. Convergent improvement is a method of double backcrossing and, as originally developed by Richey (8), was suggested as a method for testing the Mendelian explanation of hybrid vigor. In its application to plant breeding it was proposed as a means of improving each of two inbred lines without materially changing their combining ability in an F_1 cross.

Backcrossing appears a logical method when one desires to add one or two characters which a variety or inbred line lacks and to retain the many desirable characters of the variety or inbred line used as the recurrent parent. This can be accomplished most easily when the character to be added is simply inherited. Most inbred lines are great-

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[3]Figures in parenthesis refer to "Literature Cited", p. 723.

ly lacking in growth vigor when compared with normal varieties. It seems probable that multiple factors are responsible for growth vigor. Inbred lines, therefore, may differ from each other and from normal varieties by many inherited factors. Under these conditions the pedigree method of breeding used so extensively in breeding improved varieties of self-pollinated plants seems equally satisfactory as a method of breeding improved selfed lines of corn. The purpose of this paper is to report some of the results obtained from the pedigree method as used to breed improved selfed lines adapted to Minnesota conditions.

MATERIAL AND METHODS

Commercial varieties of corn grown in Minnesota are, in general, lacking in ability to withstand lodging and for this reason selection for lodging resistance has been made since 1915 when selection in self-fertilized lines was first undertaken. Several inbred lines were obtained from Minnesota commercial varieties during 1915 to 1928 that were superior to the average in non-lodging ability. In addition, several inbreds from other breeders were selected that were outstanding in ability to withstand lodging. Crosses were made in such a manner that in nearly all cases one of the parents in each cross excelled in ability to withstand lodging and in resistance to smut. Pedigree selection was practiced from the F_2 to F_6 generation for vigor of growth, earliness of maturity, ability to withstand lodging, smut resistance, and other characters.

A considerable number of the inbred lines used as parents in these crosses were studied by Hall (4), who summarized the lodging indices of the inbreds using data furnished him from the breeding plats during 1927 to 1930, and who took further data on lodging from 1931 to 1933, inclusive. In Table 1 the parental lines are placed in various groups on the basis of strength of stalk and smut reaction. The smut reaction is on the basis of average smut infection taken in recent years, 1935 to 1937, inclusive.

TABLE 1.—*Lodging and smut reaction of inbreds used as parents of crosses.*

Inbred line	Former culture	Variety source	Smut reaction, %	Lodging index*
A9	C49	Minn. No. 13	9	I
A2	C43	Minn. No. 13	40	I–
A12	C11–28	Minn. No. 13	18	S
A48	64	N. W. Dent	28	S
A39	15–28	Rustler	33	I
A26	9–29	Osterland's Dent	6	S
A25	8–29	Purdue Dent	24	S

*S = strong stalk; I = intermediate.

Crosses made in 1929 were as follows: A48 with A9, A12, and A39; A9 with A39 and A26; A12 with A39; and A39 with A25 and A26. In addition, a few cultures were grown from crosses made at the Waseca branch station including a cross of A48 × H and A48 × 4–29, crosses between an inbred culture of N.W. Dent with an inbred from Reid's Yellow Dent and Silver King, respectively. It will be noted that one of the parental inbreds excelled in smut resistance in most crosses made. Selection in self-pollinated lines was practiced from F_3 to F_6, inclusive, the number of ear cultures grown each year, showing the extent of the studies, were

as follows: F_3, 729; F_4, 538; F_5, 198. In addition to these crosses 75 to 100 ear progenies were grown of crosses between A2 with inbred cultures 46 and 47 from Minn. No. 13, these crosses being made originally to select lines that were resistant to *Gibberella saubinetii* in the seedling stage, culture A2 being outstanding in this respect. Besides selecting inbreds from crosses, further selection was made in inbred lines of Minn. No. 13, Golden Gate, and a late strain of Minn. No. 13 known as Kalmoe.

The 7 parental inbred cultures given in Table 1, 13 new inbreds selected in Minnesota from commercial varieties, 4 inbreds introduced from Wisconsin, 16 inbreds from crosses of A2 with inbreds 46 and 47 selected from Minn. No. 13, and 70 inbreds selected by the pedigree method from crosses between inbreds that excelled in ability to withstand lodging were used in studies of the relation between the characters of inbreds and their combining ability.

These inbreds were grown at University Farm during 1935 to 1937. The 110 individual cultures were grown in short row plats of approximately 25 plants each, in single plant hills spaced 1 foot apart, two replications in randomized blocks being used for each inbred line. Data were taken on each plat separately and results for the three years were averaged to give the average expression for 14 characters of each of the inbred lines. Separate analyses of variance were made for each of these characters and in each case significant variability between inbred lines was found.

The characters studied need not be described in great detail. They included date silked, plant height, ear height, leaf area, pulling resistance, root clump volume, stalk diameter, total brace roots, tassel index, pollen yield, percentage of smutted plants, ear shank length, yield index, and length of ear. Many of these characters required only a simple measurement and need not be described. Pulling resistance refers to number of pounds required to pull a plant from the ground. Root clump volume is the number of cubic inches obtained by multiplying $(\text{width})^2 \times \pi/4 \times$ depth of clump. Total brace roots is the actual number of brace and secondary roots established in the soil. Tassel index was placed on a reading of from 1 to 4, measuring the number of tassel branches and general vigor of tassel development with 4 representing the most vigorous class. Pollen yield was measured in cc after collecting pollen by bagging the tassel. Yield index was measured in percentage of the average of all cultures and expresses the relative ability of inbred lines to produce seed when self pollinated, cross pollinated, or under normal field pollination. Certain of the characters of inbreds obtained from the various crosses were summarized in frequency tables to show the extent to which it was possible to produce improved inbred lines by the methods employed.

Each of the 110 inbreds was crossed with Minn. No. 13, using the inbred as the female and the inbred-variety crosses were compared in yield trials made during 1936 and 1937, tests in 1936 being made in Meeker County only and in 1937 at the Morris branch station and in Meeker County. Each trial was made in randomized blocks using approximately 20 inbred-variety crosses per block, and including also Minn. No. 13, Minhybrid 401, and 402, three replications being made at each locality. In all cases results for each inbred variety cross are based upon the average of trials in at least two localities. When trials were available for only two localities the results were corrected on the basis of performance of check varieties. Yielding ability and moisture percentage at husking of the inbred-variety crosses were expressed as percentages of the average for the checks. Plant height in inches, ear shank length, percentage smut infection, ear length, number of rows per ear, good ears per plant, and shelling percentage were also recorded.

Simple product moment correlation coefficients were computed to express the relationship between certain characters of inbred lines and their expression in inbred-variety crosses.

Ten of the 14 characters of the inbreds that by means of correlation coefficients showed a significant association between the characters as expressed in the inbreds and yielding ability in inbred-variety crosses were correlated with each other. A multiple correlation coefficient was computed to show to what extent the variability in yield of the inbred-variety crosses was dependent upon measurable character differences of the inbred lines.

Inbred lines, obtained by the pedigree method of breeding from crosses between inbred lines as the original source, were selected that had better than average combining ability in the inbred-variety crosses. The origin of inbreds used in these crosses is as follows:

Original Cross	Inbred Cultures Selected
A48×H	A94, A96
A48×A9	A90
A9 ×A39	A99
A9 ×A26	A102, A111, A116, A122, A124
A12×A39	A131
A39×A26	A136, A143, A145, A146
A2 ×46	A148
A2 ×47	A158, A163

Single crosses between inbreds were made in such a manner that the primary difference between groups related to the origin of the inbreds. Group I consisted of crosses between inbreds with no parents in common, illustrated by A94×A99; group II had one parent in common, as illustrated by A90×A111, with the inbred parent A9 in common; and group III had both parents in common, as illustrated by the cross A102×A111.

Yield tests of the single crosses were made at University Farm, St. Paul, the Morris branch station, Meeker County, and Breckenridge. Single row plats of 12 hills each were planted for each cross and the check varieties. Randomized blocks were used, with three replications at each locality. Four check varieties, consisting of the Morris and University Farm strains of Minn. No. 13 and Minhybrids 401 and 402, were included in each block. Perfect stand hills were harvested surrounded by corn and the final yields and moisture content were placed on a percentage basis of the average of the four check varieties.

EXPERIMENTAL RESULTS

BREEDING IMPROVED INBREDS

Pulling resistance was found by Hall (4) and others to be correlated with ability to withstand lodging, and accordingly pulling resistance gives some indication of the desirability of the inbreds selected from crosses. The inbred lines are classified in Table 2 for pulling resistance.

It will be noted that the first five parental inbred lines in Table 2 originate from Minnesota varieties and are not particularly outstanding in pulling resistance. Inbred lines introduced from Purdue and Wisconsin, A25 and A26, are much superior to the Minnesota inbreds in pulling resistance. Many of the inbreds selected from

TABLE 2.—*Pulling resistance of inbred lines in relation to origin (average 1935–37), University Farm.*

Origin of lines	No. of lines in classes for resistance to pulling in lbs.						
	100	150	200	250	300	350	Total
A9	—	1	—	—	—	—	1
A2	—	1	—	—	—	—	1
A12	—	1	—	—	—	—	1
A48	1	—	—	—	—	—	1
A39	—	1	—	—	—	—	1
A26	—	—	—	1	—	—	1
A25	—	—	—	—	—	1	1
Total	1	4	—	1	—	1	7
Minn. No. 13	1	2	1	—	—	—	4
Golden Gate	1	2	2	—	—	—	5
Kalmoe	—	3	1	—	—	—	4
Wisconsin	—	1	—	2	1	—	4
A2×46	3	4	1	—	—	—	8
A2×47	3	4	1	—	—	—	8
A48×A9	1	3	3	—	—	—	7
A9×A39	—	—	1	—	1	—	2
A9×A26	2	3	17	1	—	—	23
A12×A39	—	4	3	—	—	—	7
A39×A26	1	1	13	2	2	—	19
A39×A25	—	1	6	—	—	—	7
A48×H	1	1	3	—	—	—	5
Total	13	29	52	5	4	—	103

crosses were intermediate in pulling resistance and they are superior on the average to those obtained from selfing and selection from Minnesota adapted commercial varieties, including Minn. No. 13, Golden Gate, and Kalmoe's No. 13. Root clump volume was studied in a similar manner. Thirty-five of the inbred lines obtained by the pedigree method of breeding from crosses were outside of the range of inbreds selected from Minnesota varieties and 14 of these were the equal in root volume of A25 or A26.

Percentage of smut of the inbred lines is given in Table 3. Selection for smut resistance was made during the segregating generations. Selfed ears from smut-free plants were used in propagating the cultures and selection was made also for cultures that were least severely infected with smut.

Seventy-one of 103 new inbred lines recorded in Table 3 were placed in the two lower classes for smut infection, while only 3 of the 7 original inbred lines used as parents were placed in these classes. From a considerable number of years experience it seems fair to conclude, that under the conditions of the experiment, a large proportion of the new inbreds is superior to normal Minnesota No. 13 and Rustler in resistance to smut.

TABLE 3.—*Smut percentage of inbred lines in relation to their origin (average 1935–37), University Farm.*

Origin of lines	No. of lines in smut percentage classes						
	5	14	23	32	41	50	Total
A9	1	—	—	—	—	—	1
A2	—	—	—	—	1	—	1
A12	—	1	—	—	—	—	1
A48	—	—	—	1	—	—	1
A39	—	—	—	1	—	—	1
A26	1	—	—	—	—	—	1
A25	—	—	1	—	—	—	1
Total	2	1	1	2	1	—	7
Minn. No. 13	—	—	—	2	2	—	4
Golden Gate	—	3	2	—	—	—	5
Kalmoe	1	2	—	—	1	—	4
Wisconsin	4	—	—	—	—	—	4
A2×46	6	1	1	—	—	—	8
A2×47	2	3	1	2	—	—	8
A48×A9	2	4	1	—	—	—	7
A9×A39	—	1	—	1	—	—	2
A9×A26	9	9	2	3	—	—	23
A12×A39	—	2	3	2	—	—	7
A39×A26	7	8	1	2	1	—	19
A39×A25	1	2	2	1	—	1	7
A48×H	—	4	—	—	1	—	5
Total	32	39	13	13	5	1	110

COMBINING ABILITY OF INBREDS

The combining ability of inbreds was determined by crossing each with Minnesota No. 13, using the method that has been accepted rather generally (2, 3, 5, 6), as a means of discarding lines of low combining ability. In most cases data are available from trials in Meeker County during 1936 and 1937 and at the Morris branch station in 1937. For two of the parental inbreds, A12 and A48, data were obtained only at Meeker County in 1936. Unfortunately, inbreds 46 and 47 were not tested in these top crosses, hence their combining ability can not be compared with that of the 16 inbreds descending from crosses involving these two lines. The results are shown in Table 4.

For the purpose of comparison the six frequency classes for combining ability can be divided into two groups, three lower classes including the parental inbreds selected from Minnesota No. 13 and Northwestern Dent and three upper classes including A39 selected from Rustler, A26 from Osterland's Dent, and A25 from Purdue Early. Inbreds selected from the cross of A48×A9, both low combining parents, were somewhat superior to the parents, on an average, in combining ability. Crosses of A9×A26 and A12×A39 were made between inbreds, one parent in each cross being of low combining

TABLE 4.—*Yielding ability in percentage of the checks of inbred-variety crosses in relation to the origin of the inbred lines.*

Variety source	Origin of lines	Yield classes in percentage						
		72	83	94	105	116	127	Total
Minn. No. 13	A9(49)	—	1	—	—	—	—	1
Minn. No. 13	A2(43)	—	—	1	—	—	—	1
Minn. No. 13	A12*(11–28)	—	—	1	—	—	—	1
N. W. Dent	A48*(64)	—	1	—	—	—	—	1
Rustler	A39(15–28)	—	—	—	—	—	1	1
Osterland's Dent	A26(9–29)	—	—	—	1	—	—	1
Purdue Early	A25(8–29)	—	—	—	—	—	1	1
Total			2	2	1		2	7
Minn. No. 13	Long Time Selfed	—	1	2	1	—	—	4
Golden Gate	Long Time Selfed	—	1	3	1	—	—	5
Kalmoe	Long Time Selfed	—	1	2	1	—	—	4
Wis. lines	Long Time Selfed	—	—	1	2	1	—	4
Minn. No. 13	A2×46	—	2	3	3	—	—	8
Minn. No. 13	A2×47	—	—	2	4	1	1	8
Crosses between inbreds	A48×A49	—	1	4	2	—	—	7
Crosses between inbreds	A9×A39	—	—	—	2	—	—	2
Crosses between inbreds	A9×A26	1	—	5	12	5	—	23
Crosses between inbreds	A12×A39	—	—	1	5	—	1	7
Crosses between inbreds	A39×A26	—	—	—	5	14	—	19
Crosses between inbreds	A39×A25	—	—	—	3	3	1	7
Crosses between inbreds	A48×H	—	—	—	2	3	—	5
Total		1	6	23	43	27	3	110

*Inbred-variety cross yield 1936 only.

ability while the other parent was in one of the three upper classes in combining ability. A12 proved superior to A9 in combining ability while A39 was superior to A26. There seems to be some indication that inbreds of high combining ability can be selected relatively frequently from crosses of this nature. Twenty-six inbred lines were selected from crosses between A39, of extremely high combining ability, with A26 placed in class 105 for combining ability and from A39 with A25 where both parents were superior in combining ability. All 26 inbreds selected from these crosses were in the upper three classes for combining ability. There is considerable evidence that leads to the conclusion that the combining ability of inbreds selected by the pedigree method is associated with that of the inbred parents.

RELATIONSHIP BETWEEN CHARACTERS OF INBREDS AND OF INBRED-VARIETY CROSSES

The characters of the inbreds were determined from data collected from small plats grown at University Farm with two replications each year during 1935 to 1937. Data on inbred-variety crosses were obtained at three localities, although in several crosses the yield trials

were conducted in two localities only. Correlations between characters of the 110 inbreds and their inbred variety crosses are given in Table 5.

TABLE 5.—*Correlations between characters of 110 inbred lines and similar characters in inbred-variety crosses.*

Inbred character	Inbred-variety cross character	*r*
Date silked	Moisture percentage at husking	0.5746
Plant height	Plant height	0.3677*
Smut percentage	Smut percentage	0.4638
Ear length	Ear length	0.4661
Shank length	Shank length	0.5431

*All correlations exceed the 1% point.

Correlation coefficients were computed for average date of silking of the inbreds and moisture content at husking of the inbred-variety crosses, while the extent of correlation between plant height, smut percentage, ear length and shank length was determined for the same characters in the inbred and in the inbred variety crosses. The correlations in Table 5 are all positive and exceed the 1% point in level of significance, the extremes being 0.3677 for plant height and 0.5746 for that between date of silking of the inbreds and moisture percentage of the crosses.

Correlations were computed between the yielding ability of inbred-variety crosses and other characters of the inbred-variety crosses, including moisture percentage at husking, plant height, shank length, percentage of smut infection, ear length, rows per ear, good ears per plant, and shelling percentage. With significant values at the .05 and .01 points of 0.188 and 0.246, respectively, the following significant positive correlations were obtained: Between yield and moisture content at husking, 0.3146; between yield and ear length, 0.5257; between yield and good ears per plant, 0.2117, while there was a negative correlation between yield and percentage of smut infection of −0.2155. Associations between the yields of inbred-variety crosses and plant height, number of rows per ear, and shelling percentage of the inbred-variety crosses ranged from −0.0234 to +0.0526, showing no significant association.

All possible correlations between 13 characters, 12 of these being characters of the inbred lines and the other being the yielding ability of the inbred-variety cross, were computed and the results are given in Table 6.

Ear length of the inbreds did not give a significant correlation coefficient with any other characters except yield index of the inbreds, pollen yield, and yield index of the inbred-variety crosses. Nearly all other interrelations between characters (Table 6) gave positive correlations of significant value. Date of silking of the inbreds was significantly correlated with all other characters except yield index of the inbreds and ear length. All of the measurable characters that represent growth vigor showed in general a positive association with each other. All 12 characters of the inbreds given in Table 6 gave positive and significant correlations with yield of the inbred-variety crosses and

TABLE 6.—*Total correlations between 12 characters of the 110 inbreds and yielding ability of inbred-variety crosses.*

Characters correlated*	2	3	4	5	6	7	8	9	10	13	14	15
Inbred 1	0.5118	0.6081	0.4819	0.6465	0.6193	0.5469	0.3831	0.3741	0.2230	0.0731	−0.0591	0.4742
Inbred 2	—	0.7560	0.4419	0.4817	0.4294	0.3959	0.2588	0.1855	0.3568	0.2549	0.0812	0.2717
Inbred 3	—	—	0.4324	0.5388	0.5025	0.4133	0.3522	0.3317	0.2201	0.1512	−0.0074	0.4110
Inbred 4	—	—	—	0.4954	0.4417	0.4797	0.3959	0.2893	0.1847	0.2040	0.0815	0.2889
Inbred 5	—	—	—	—	0.7623	0.5095	0.6013	0.4052	0.2085	0.1484	0.0352	0.4486
Inbred 6	—	—	—	—	—	0.5545	0.7424	0.3896	0.2894	0.1947	0.0320	0.5430
Inbred 7	—	—	—	—	—	—	0.5355	0.2384	0.2674	0.2065	0.1549	0.4069
Inbred 8	—	—	—	—	—	—	—	0.2559	0.2245	0.2025	0.0683	0.4463
Inbred 9	—	—	—	—	—	—	—	—	0.1990	−0.0029	−0.0342	0.1902
Inbred 10	—	—	—	—	—	—	—	—	—	0.3451	0.3202	0.2566
Inbred 13	—	—	—	—	—	—	—	—	—	—	0.6403	0.2474
Inbred 14	—	—	—	—	—	—	—	—	—	—	—	0.2768
Inbred 15	—	—	—	—	—	—	—	—	—	—	—	—

Significant value of r for P of .05 = 0.188
Significant value of r for P of .01 = 0.246

*Key to characters:
1 Inbred date silked
2 Inbred plant height
3 Inbred ear height
4 Inbred leaf area
5 Inbred pulling resistance
6 Inbred root volume
7 Inbred stalk diameter
8 Inbred total brace roots
9 Inbred tassel index
10 Inbred pollen yield
13 Inbred yield index
14 Inbred ear length
15 Inbred-variety cross yield

all exceeded the .01 point except the correlation between tassel index of inbreds and the yield of inbred-variety crosses.

A multiple correlation was computed between the yield of inbred-variety crosses and the 12 characters of the inbred lines given in Table 6. An R value of 0.6660 was obtained, while the value of R at the 1% point for degrees of freedom of 100, i.e., 3 greater than in the problem, was .470. Using the square of 0.660, or 0.4435, we may conclude that 44% of the squared variability in yield of the inbred-variety crosses was dependent upon the 12 characters of the inbred parents in the inbred-variety crosses.

It is generally known that there is a direct correlation, other things being equal, between length of growing season to maturity and yielding ability. The multiple correlation coefficient, holding constant date of silking, was calculated by means of a formula given by Tappan where

$$1-R^2_{15.2,3,4,5,6,7,8,9,10,13,14}\left|\,1\,\right| = \frac{1-R^2_{15.1,2,3,4,5,6,7,8,9,10,13,14}}{1-R^2_{15.1}}$$

A calculated value of R of 0.5310 was obtained showing that if date of silking is held constant that 28% of the total squared variability in yield of the inbred-variety crosses is directly related to the characters studied in the inbred lines other than date silking.

The breeding of improved inbred lines is of direct value in a corn breeding program as a means of reducing the cost of production of three-way and double crossed seed. Since there is a significant association as measured by the correlation coefficient between the characters of inbred lines that measure growth vigor and the combining ability of inbred lines in inbred-variety crosses, it would appear that the production of improved inbreds, as measured by the development of the inbreds themselves, will lead, on the average, to the development of higher yielding double crosses.

YIELDING ABILITY OF INBREDS IN F_1 CROSSES

Inbred lines that combined well in inbred-variety crosses were selected and their yielding ability in single crosses was studied in relation to their origin. All inbreds used in this study were selected by the pedigree method of breeding from single crosses between inbreds and subsequent selection during the segregating generations for vigor of plant, ability to withstand lodging, and resistance to smut.

Three groups of single crosses were grown, as described in the section on materials and methods, giving the pedigrees of the parents of a single cross in each of the three groups. Group I had no parents in common; group II had one parent in common; and group III had both parents in common.

Single crosses from each of the three groups were grown in randomized blocks, the Morris and University Farm strains of Minnesota No. 13 and the two early double crosses, Minhybrids 401 and 402, being included in each block. Two separate series of single crosses from inbreds with no parents in common were grown, or 43 crosses

in all. Fifteen single crosses and checks were grown in separate randomized blocks for groups II and III. Yielding ability of each of the single crosses in the three groups was compared with checks grown in the same randomized block. To determine whether the three groups of crosses were comparable from the standpoint of combining ability, the average combining ability of the inbred parents, for each of the single crosses, was determined by using the combining ability of each inbred as measured in an inbred-variety cross. Thus, as an illustration, the combining ability of A94×A99 was as follows:

Inbred Variety Cross	Percentage Yielding Ability	Percentage Moisture at Husking
A94×Minn. No. 13	115	123
A99×Minn. No. 13	102	98
Average	108.5	110.5

The average percentage yielding ability and moisture percentage at husking in inbred-variety crosses of the parents of each single cross in each of the three groups of single crosses is given in Table 7. The percentages used are on the basis of 100 for the average of two strains of Minn. No. 13, Minhybrids 401 and 402, which were grown in each of the four randomized blocks.

TABLE 7.—*Average percentage yielding ability and moisture percentage at husking in inbred-variety crosses of inbreds used in the three groups of single crosses differentiated on the basis of genetical origin.*

Group	Number single crosses	Percentage combining ability	Moisture percentage
I	43	107.3	103.3
II	15	110.7	114.6
III	15	110.0	110.5

In general the three groups are of similar genetical value in combining ability, group I being somewhat earlier than group II or group III and somewhat lower in average combining ability.

Standard errors for yield in bushels per acre were computed separately for each of the four locations and for each of four randomized block trials. An average standard error was computed from analyses of variance, using the formula

$\frac{1}{4}\sqrt{S.E.^2_{U.F.}+S.E.^2_{Me}+S.E.^2_{M}+S.E.^2_{B}}$ where U.F., Me, M, and B refer, respectively, to University Farm, Meeker, Morris, and Breckenridge. This S.E. was then multiplied by $2\sqrt{2}$ to give a S.E. of difference that was accepted as of probable significance and that was used in interpreting the comparative yielding ability of the F_1 crosses. These S.E.'s for yield in bushels per acre and moisture content of ears at husking are summarized in Table 8.

In these yield trials two strains of Minn. No. 13 were grown and the two Minhybrids, 401 and 402. Minhybrids 401 and 402 have been outstanding in yielding ability in north central Minnesota. In the 2-year average in the commercial hybrid field trials as reported by

TABLE 8.—*Average standard errors for yield trials at four localities multiplied by $2\sqrt{2}$.*

Number of parents in common of inbreds	Series of yield trials	$2\sqrt{2}$ S. E.	
		Yield, bu.	Moisture content, %
0	1	5.5	1.5
0	2	4.9	1.4
1	3	5.3	1.5
2	4	5.2	1.7

Crim (1) for the test in Bigstone County in 1937 and in Ottertail in 1938, Minhybrid 401 gave the highest average yield of any of the hybrids tested and with lower moisture content than any hybrid except Minhybrid 402. In the group of hybrids considered to be adapted to the region, Minhybrid 402 was second to Minhybrid 401 in yield in bushels per acre. In the only other commercial yield trial where Minhybrid 401 is well adapted, which was conducted in Meeker County for two years, 1937–38 inclusive, Minhybrid 401 led the five crosses that seemed adapted to the locality.

TABLE 9.—*Average yield in bushels and average moisture content at husking of Minhybrids 401 and 402 compared with Minn. No. 13 in each of four series of randomized block tests and at four locations, University Farm, St. Paul, Meeker Co., Morris branch station, and Breckenridge, 1938.*

Variety of cross	Yield in bushels for series					Moisture percentage for series				
	1	2	3	4	Av.	1	2	3	4	Av.
Minhybrid 401	59.4	60.5	62.2	63.8	61.5	24.4	23.9	24.1	24.0	24.1
Minhybrid 402	52.8	55.7	54.9	55.0	54.6	21.8	20.8	22.3	21.5	21.6
U. Farm No. 13	53.6	52.0	55.9	50.8	53.1	28.5	27.8	29.6	29.7	28.9
Morris No. 13	53.2	55.3	54.2	54.2	54.5	26.9	26.6	25.8	27.2	26.6

Minhybrid 402 was much earlier than Minn No. 13 (Table 9) and yielded practically the same. Minhybrid 401 yielded 12.8% more than the Morris strain of Minn. No. 13 and was several days earlier in maturity than the Morris strain and much earlier than the University Farm strain of Minn. No. 13. These two hybrids, Minhybrids 401 and 402, are therefore rather outstanding in yielding ability for early corn under the conditions of these trials.

The yielding ability and moisture content of each of the single crosses was expressed relative to the same characters for Minhybrids 401 and 402, the results being summarized in Table 10 in three groups differentiated on the basis of the origin of the original inbred lines.

The standard errors given in Table 8 were used as measures of significant differences and the single crosses were compared with Minhybrids 401 and 402. Cross A94×A99 in group I, for example, yielded 54.0 bushels with a moisture content of 25.5%. Minhybrid 401 yielded 59.4 bushels with a moisture content of 24.4%, while Minhybrid 402 yielded 52.8 bushels with a moisture content of 21.8%

TABLE 10.—*Comparison of single crosses with Minhybrids 401 and 402 on the basis of yield and moisture percentage at husking in yield trials at four localities in 1938.*

Origin of crosses	Not significantly lower in yielding ability than Minhybrid 401 or 402 and with moisture content at husking in four classes based on significant differences in moisture content				Significantly lower in yielding ability than Minhybrids 401 and 402
	Earlier than 402	Equal to 402	Equal to 401	Later than 401	
Group I...	2	12	12	2	15
Group II..	—	—	3	3	9
Group III.	—	1	—	—	14

In this trial differences of yield of 5.5 bushels and of moisture content of 1.5% were accepted as significant (Table 8). Hybrid A94×A99 was accepted as in the same group as Minhybrid 401 for yielding ability and moisture content at husking. Many of the single crosses were superior to the standard double crosses in yielding ability. In the summary there was no attempt to differentiate between those that were superior to Minhybrids 401 and 402 in yielding ability.

As will be noted from Table 10, 28 of 43 hybrids in group I were accepted as equal or superior to Minhybrids 401 or 402 and 15 were significantly lower in yielding ability, while 9 of 15 in group II were significantly lower in yielding ability than Minhybrids 401 and 402 and only 1 out of 15 in group III was accepted as equal to Minhybrids 401 and 402 in yielding ability and time of maturity.

These results are not greatly different from those reported by Wu (11). They show a direct relation between the origin of inbred lines and their combining ability in crosses as would be expected on the theoretical basis. It is also of interest to note that of 43 single crosses from crosses between unrelated inbreds, when inbreds are used that have previously proved to be good combiners as tested in inbred-variety crosses, that 28 of these, or 65%, were accepted as of equal yielding ability to double crosses known to be outstanding for the regions of the trials.

SUMMARY OF RESULTS

Inbred lines were bred by the pedigree method from crosses between inbreds where as a rule one parent at least of each cross was outstanding in ability to withstand lodging and in smut resistance. Selection during the segregating generations was made in selfed lines for plant vigor, smut resistance, and ability to withstand lodging. Evidence was given to show the extent to which the inbreds were improved in various characters and, in general, the methods used appeared to lead to distinct improvement in many characters.

The inbreds produced by the pedigree method were studied in inbred-variety crosses to determine their combining ability. The evidence as given indicates that lines of good combining ability are obtained more frequently from crosses between inbreds that them-

selves are good combiners than from crosses between inbreds that are low in combining ability. Combining ability, therefore, is an inherited character.

Fourteen characters of inbreds, many of which were related to growth vigor, were studied for a 3-year period in small replicated plats with two replications. Correlations were calculated to show the relationship between certain characters of the inbreds and of the inbred-variety crosses. These included date of silking of the inbreds and moisture content at husking of inbred-variety crosses, while plant height, smut percentage, ear length, and shank length of the inbreds was correlated with the same characters in inbred-variety crosses. Correlation coefficients, based on 110 strains, ranged from 0.3677 for plant height to 0.5746 for maturity, all exceeding the 1% point for level of significance.

Twelve characters of the inbreds, by means of total correlations, were found to be significantly related to yielding ability in inbred-variety crosses. The correlations ranged from +0.1902 for tassel index of inbreds and yield of inbred-variety crosses to +0.5430 for root volume of inbreds and yield of inbred-variety crosses. In these studies the significant values of r for a P of .05 and .01, respectively, were +0.188 and +0.246, all coefficients exceeding the 1% point except the correlation between tassel index and yield.

A multiple correlation coefficient of .6660 was obtained for association between yield of inbred-variety crosses and the following characters of inbred lines, date silked, plant height, ear height, leaf area, pulling resistance, root volume, stalk diameter, total brace roots, tassel index, pollen yield, yield index, and ear length. When date of silking was held constant a partial multiple correlation coefficient of .5310 was obtained for the correlation between inbred-variety yield and 11 other characters of the inbreds.

Inbreds of good combining ability were selected from inbred-variety crosses. These inbreds were obtained by the pedigree method of breeding. They were studied in F_1 single crosses in three groups. Group I where the inbred parents for each single cross were selected from crosses between inbreds in such a manner that there were no parents in common in the ancestry of the single cross; group II with one parent in common; and group III with both parents in common. On the average, the F_1 crosses in group I were superior in yielding ability to those in group II and far superior to those in group III. From 43 single crosses in group I, 28 were not significantly lower in yielding ability and moisture percentage to Minhybrids 401 or 402, while similar relationships for group II and group III gave 6 out of 15 and 1 out of 15, respectively, that were not significantly lower in yielding ability and moisture percentage than these double crosses.

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NOTES

AN APPARATUS MADE FROM GLASS FOR THE CONTINUOUS WATERING OF POT CULTURES[1]

FOR experiments pertaining to the study of the effect of such minor elements as I, Mn, Cu, Zn, B, etc., upon the growth and development of plants, it is essential to use cultures to which have been added mineral nutrients of known composition. Any contamination of the cultures with the particular elements under study would cause an error. Not only must the mineral nutrients be carefully analyzed, but also metal-free water must be used with the experiment. This means that any method of watering the pots must be one in which no metal is allowed to come in contact with the water at any time. Water must be handled in glass or silica containers.

Water may be added manually to the pots, daily weighing the pots to determine the loss of water and adding enough water to bring the culture to the desired level of water content. This requires considerable time and trouble on the part of the investigator, especially if he is handling a large number of pots.

An improved and simplified apparatus for watering experimental pot cultures in greenhouse work has been constructed by the authors. The apparatus is an improvement of the form previously reported by Calfee and McHargue.[2]

It makes use of the capillary action of sand or soil and provides a constant supply of water in each pot, regardless of how fast the water is transpired by the plants. The apparatus can be constructed entirely of glass by anyone who has had some experience in glass blowing. With the exception of the reservoirs, which are soft glass bottles, and a 250-cc beaker, pyrex glass tubing is used.

A diagram of the assembly of the apparatus is shown in Fig. 1. The bench (1) supports 1-gallon glass bottles (2) which are used as

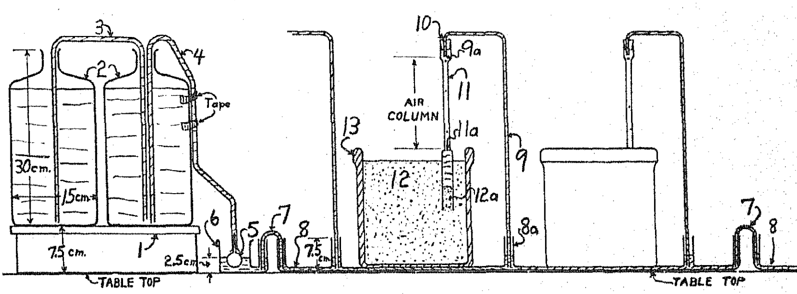

FIG. 1.—Diagram of apparatus.

[1]The investigation reported here was carried out in connection with a project of the Kentucky Agricultural Experiment Station, Lexington, Ky., and is published by the permission of the Director. Read before the Division of Chemistry, at the 26th annual meeting of the Kentucky Academy of Science, Murray State Teachers College, April 28, 1939.

[2]CALFEE, R. K., and MCHARGUE, J. S. An automatic watering system for pot cultures. Jour. Amer. Soc. Agron., 29:797. 1937.

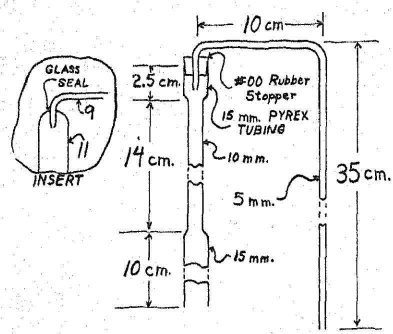

FIG. 2.—Showing dimensions and detail of float.

water reservoirs. Two or more of the bottles may be connected by means of siphons (3) constructed of 7-mm pyrex tubing. A siphon (4) made of the same size tubing is inserted in one of the bottles and held in place by adhesive tape or paper stickers on the side of the bottle. At the lower end of this tube is a pyrex glass float (5) which operates a ground needle-valve arrangement. Dimensions and greater detail of this float are shown in Fig. 2. This float maintains a constant level of water in the 250-cc beaker (6). This water level is 2.5 cms above the table top and is the same in the tube (8) which is connected to the beaker by means of the side tube (6a) and siphon (7).

The tube (8) is the "main" for the system. It is made with vertical side tubes (8a) spaced the same distance as one wishes between centers of adjacent pots (13). The pots are filled with purified sand (12) of rather fine grain. The watering tube (11) is placed in the sand as indicated and connected by means of the siphon (9) and rubber stopper (10) to the "main" tube. Details of tubes (9) and (11) are shown in Fig. 3. The stopper (10) holding (9) is placed tightly in the tube (11) so that when (9) is filled with water and water drips from the tip (9a) the water level in (11) is at (11a). The height of the air column in (11) is adjusted at 15 cms and referring to the curve in Fig. 4, which has been experimentally determined, the water content of the sand will be 23.7 grams per 100 grams of sand.

The position of the curve in Fig. 4 is determined by the kind of sand or soil in the pot. The curve illustrated indicates, for one type of sand, the water content in one gallon pot (containing 4 kiolgrams of sand) for a particular height of air column in (11). The water content of the pot can be set, within a limited range, by adjusting the height of this air column. If one desires to eliminate the stopper (10), which incidentally does not come in contact with water, he may do so by sealing (9) and (11) together as

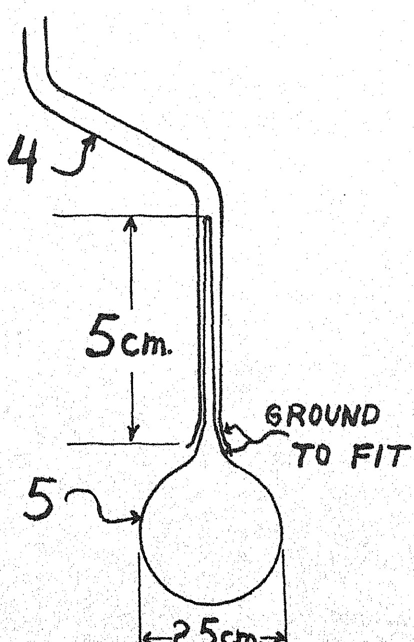

FIG. 3.—Details of tubes.

indicated in the insert in Fig. 2. This type of tube is more clumsy to handle and much more susceptible to breakage.

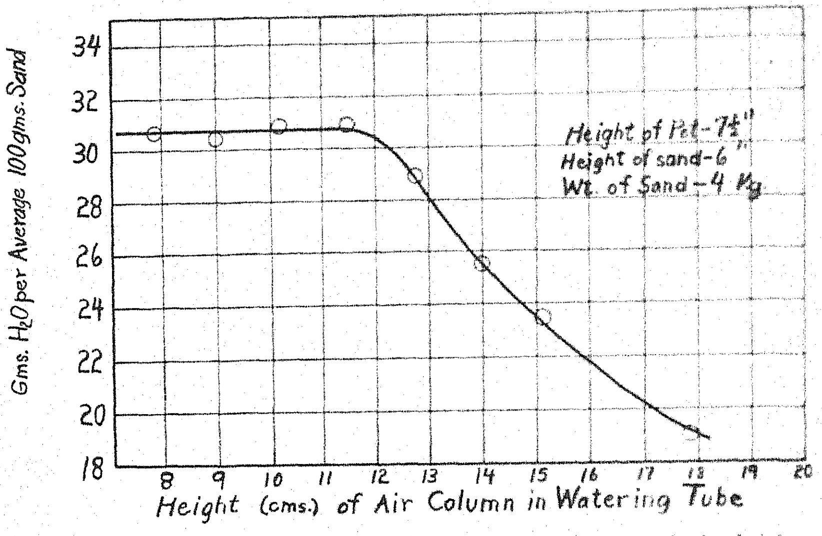

FIG. 4.—Curve showing water content in a pot of sand for a particular height of air column in the tube.

The action of the apparatus is as follows: In effect the tubes (9) and (11) combined are a siphon. Capillary action of sand in the pot creates a force which pulls the water up the tube (9). This force is dependent upon the amount of water in the sand. Low water content in the sand permits the sand to exert a greater force. If the air column in the watering tube is short, more water will be drawn over by the sand until the force diminishes to the point that it is just sufficient to hold a column of water the same height as the air column. As water is absorbed by a plant in the sand or evaporates, the force increases and water drips from the tip (9a). Water in the lower part of (11) stands at the height (11a) and is in contact with sand (12a) at the bottom of the tube. Water is absorbed from the system by the sand at this point.

Occasionally an air leak will occur around the stopper (10) or the base of (11) which normally is sealed by wet sand (12a). If the siphon is broken, the tube must be refilled with water and the leak corrected before normal operation can be resumed. This is accomplished by removing the stopper (10) and filling (11) with distilled water to a point determined by experiment so that when the air is drawn out of (9) into (11) the level (11a) will be the correct distance from (9a). Only a few seconds are required to make this adjustment. Normal operation of the watering apparatus is evident by the dripping of water from the tip (9a).

The efficiency of this type of apparatus in supplying water to the cultures was shown by Calfee and McHargue in the above-metnioned report. This watering apparatus has functioned satisfactorily during

the growth from seed to maturity of a few species of plants. It eliminates the necessity of weighing the pots and maintains a uniform water content in the cultures during the time the plants are making their growth. A single worker need not spend more than half an hour daily in watering as many as 100 pot cultures growing simultaneously. —E. B. OFFUTT, R. K. CALFEE, AND J. S. MCHARGUE, *Dept. of Chemistry, Kentucky Agricultural Experiment Station, Lexington, Ky.*

A METHOD OF INDUCING AN EPIPHYTOTIC OF RUST IN GRAIN BREEDING NURSERIES

IN order that selections for rust resistance in the small grains can be made satisfactorily, it is important that the disease be present uniformly and in considerable abundance. Frequently, nature unaided does not provide conditions suitable for bringing about the desired amount of infection. Some years the disease appears so late in the season that there is little opportunity to make selections and in some sections natural infection does not always occur. Furthermore, since it has been demonstrated that rust resistance in cereals may vary with the stage of growth, it seems very desirable to establish rust in breeding nurseries as early in the season as practical. The method described below has been used successfully for the past three years in producing an earlier, more uniform, and more severe outbreak of crown rust in the oat nursery at the Georgia Experiment Station.

All alleyways and borders are planted with one drill width (about 4 feet) of a rust-susceptible variety like Winter Turf. Plants of this sus-

FIG. 1.—Cloth-covered frame enclosing rusted plants. Crown rust infection on Winter Turf oats in this border was so severe that the oats failed to head.

ceptible variety are heavily infected with rust by artificial inoculation in the greenhouse during late winter and these plants are then set at intervals throughout the borders in early spring. Approximately 16 square feet space about the rusted plants is then covered by a wood frame 4 feet square and 2 feet high. The frame is covered with cotton sheeting. Fig. 1 shows one of these frames in position in the field.

Late in the evening of each of several succeeding days the ground within and immediately surrounding this frame is watered and the cloth covering is draped down on all sides and thoroughly wetted. The frame then serves as a moist chamber and maintains atmospheric conditions quite favorable for infection and spread of rust. It also affords protection to the transplanted plants from spring frosts. After the plants growing on the area covered have been inoculated, the frames may then be moved to other locations. Only a few infection centers are necessary if the rust-susceptible variety occurs frequently in the planting order.

Rust infection induced in the manner described, especially when started early in the season, usually spreads rapidly from these infection centers through the rust-susceptible border variety if later conditions are at all suitable. Usually a very general prevalence of rust infection may be established in the breeding nursery while nearby fields show little or no rust. While this method of inducing an artificial epiphytotic of rust has only been applied in connection with the oat breeding program, the author believes that it may very well be employed in initiating early infection of those rusts attacking other grains.—S. J. HADDEN, *Georgia Agricultural Experiment Station, Experiment, Georgia.*

A METHOD OF PREPARING SOME NATIVE GRASS SEEDS FOR HANDLING AND SEEDING[1]

THE reestablishment of grass on barren range and on abandoned cultivated lands is of increasing interest and importance throughout the Great Plains. The lack of sufficient adapted, introduced, or cultivated species makes it desirable to use native grass species. One of the most serious problems in the handling of these species is seed character. For species to be useful in the regrassing program, it should be possible to seed them through the ordinary grain drill. If this is not possible, the species can be of only minor value.

Several of the more important species of native grasses have seed characters that make them difficult to clean and virtually impossible to seed with standard drill equipment. Some have long awns, and some have a combination of awn and various types of pubescence on the seed coat.

An attempt has been made to treat mechanically some grass seeds for the removal of awns and hairs. A hammer mill was first used in

[1]This paper is a contribution from the U. S. Department of Agriculture, Soil Conservation Service Nursery Section, on work done at Mandan, North Dakota, in cooperation with J. T. Sarvis, Bureau of Plant Industry, Division of Dry Land Agriculture, and George A. Rogler, Division of Forage Crops and Diseases, at the Northern Great Plains Field Station, Mandan.

ceptible variety are heavily infected with rust by artificial inoculation in the greenhouse during late winter and these plants are then set at intervals throughout the borders in early spring. Approximately 16 square feet space about the rusted plants is then covered by a wood frame 4 feet square and 2 feet high. The frame is covered with cotton sheeting. Fig. 1 shows one of these frames in position in the field.

Late in the evening of each of several succeeding days the ground within and immediately surrounding this frame is watered and the cloth covering is draped down on all sides and thoroughly wetted. The frame then serves as a moist chamber and maintains atmospheric conditions quite favorable for infection and spread of rust. It also affords protection to the transplanted plants from spring frosts. After the plants growing on the area covered have been inoculated, the frames may then be moved to other locations. Only a few infection centers are necessary if the rust-susceptible variety occurs frequently in the planting order.

Rust infection induced in the manner described, especially when started early in the season, usually spreads rapidly from these infection centers through the rust-susceptible border variety if later conditions are at all suitable. Usually a very general prevalence of rust infection may be established in the breeding nursery while nearby fields show little or no rust. While this method of inducing an artificial epiphytotic of rust has only been applied in connection with the oat breeding program, the author believes that it may very well be employed in initiating early infection of those rusts attacking other grains.—S. J. HADDEN, *Georgia Agricultural Experiment Station, Experiment, Georgia.*

A METHOD OF PREPARING SOME NATIVE GRASS SEEDS FOR HANDLING AND SEEDING[1]

THE reestablishment of grass on barren range and on abandoned cultivated lands is of increasing interest and importance throughout the Great Plains. The lack of sufficient adapted, introduced, or cultivated species makes it desirable to use native grass species. One of the most serious problems in the handling of these species is seed character. For species to be useful in the regrassing program, it should be possible to seed them through the ordinary grain drill. If this is not possible, the species can be of only minor value.

Several of the more important species of native grasses have seed characters that make them difficult to clean and virtually impossible to seed with standard drill equipment. Some have long awns, and some have a combination of awn and various types of pubescence on the seed coat.

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connection with the cleaning of grass seed in 1935.[2] Recent trials at the Soil Conservation Service Nursery at Mandan, North Dakota, indicate that the method is economical and also practical from the standpoint of seed improvement.

The method described below was devised to overcome sufficiently the difficulties in seed character in order to allow passage of the seed through the ordinary drill. The equipment used was the ordinary seed cleaning equipment, chiefly thresher and fanning mill, plus a hammer mill.

The hammer mill is of somewhat different design than that ordinarily used. The hammers are straight, thin bars of iron, lacking the articulated head which is usual in commercial machines. They are swung freely from a triangular frame, and clear the screen sufficiently so that there is no cutting or mashing action between them. The hammers at the intake are short and are graduated to a greater length toward the outlet, with the result that the hammering process grows more severe as the materials pass further through the body of the machine. The screen area is large, and screens are available in 13 sizes, from 1/40-inch to 1-inch openings. The chief advantage of this mill over some others is that it will operate at low speeds.

The seed was passed through the hammering process either from the thresher or from the fanning mill. The process was varied by changing the screen, the speed of the operation, and the amount of material held on the screen. It was fundamentally the same for all species, the difference lying in the kind and amount of material to be removed (Table 1).

SPECIES PROCESSED

Big bluestem.—Big bluestem (*Andropogon furcatus*) is awned, has ciliate pedicles, and a sterile pedicellate spikelet. The hammering removed a high percentage of the awns, the pedicellate spikelet, and part of the cilia. Recleaning once was sufficient after processing.

Blue grama.—The blue grama (*Bouteloua gracilis*) spikelet is composed of an awned fertile floret and an awned, densely bearded, rudimentary floret. It was cleaned roughly to remove the stems and other coarse waste before treating. The mill removed most of the rudiments and awns and polished the seed.

Indian ricegrass.—The problem with Indian ricegrass (*Oryzopsis hymenoides*) was somewhat different from that encountered in handling most species. The awn is readily deciduous and the callus is long pilose with silky white hairs 3 mm long. The glumes cling to about 50% of the seed, as do portions of the slender panicle branches. The processing in this species must be carefully controlled to prevent breakage of the seed; but the hairs, glumes, and parts of the panicle can be removed entirely. After one run through the hammer mill, the seed was screened and fanned. This separated the seed which was completely free of hairs. That portion not completely clean was re-run through the hammering process. As the seed is heavy and smooth and of a regular shape, the purity can be raised to very nearly 100%

[2]Work done at Soil Conservation Nursery, Ames, Iowa, by G. L. Weber, under the direction of Jess L. Fults.

TABLE 1.—*Results of process on purity, weight per bushel, and seeding properties of various species.*

Species	Purity, %*		Weight per bushel, lbs.		Value for seeding through a grain drill			
					Before treatment		After treatment	
	Before treatment	After treatment	Before treatment	After treatment	Low rate	Desirable rate	Low rate	Desirable rate
Agropyron cristatum†	—	—	—	—	Good	Excellent	—	—
Andropogon furcatus	70.0	94.1	9.0	23.0	None	None	Fair	Good
Bouteloua curtipendula	20.0	86.0	7.5	24.5	None	Poor	Excellent	Excellent
Bouteloua gracilis	86.0	91.0	7.5	23.0	None	None	Poor	Good
Elymus canadensis	75.0	94.0	7.5	24.0	None	None	—‡	—‡
Elymus junceus	98.0	99.0	15.0	19.0	None	Poor	Good	Excellent
Oryzopsis hymenoides	90.0	99.4	23.5	53.5	None	Poor	Excellent	Excellent
Stipa viridula	80.0	95.0	31.0	33.0	None	Poor	Excellent	Excellent

*Purities given in both columns are those obtained within reasonable limits of economy with a fanning mill of commercial type.
†*Agropyron cristatum* does not enter into treatment trials but is included as a standard for judging seeding values.
‡This species not included in drilling trials.

by the polishing, even though it is not fanned after threshing and before hammering.

Sand reed grass.—Sand reed grass (*Calamovilfa longifolia*) presented a problem comparable to Indian ricegrass and has been treated with the same good results.

Canada wild-rye.—Canada wild-rye (*Elymus canadensis*) has the longest awn of any of the species treated. It is not only impossible to drill this seed before processing, but it is difficult to clean it. The treatment removed the awns almost completely. The palea and lemma are fastened tightly to the caryopsis and are not removed by the treatment. After hammering, the seed was easily cleaned to a good purity by screening and fanning. Ordinarily it is not necessary to pass this seed through the fanning mill before processing.

Russian wild-rye.[3]—Russian wild-rye (*Elymus junceus*), an introduced species, was first tried at this station about 10 years ago and is now receiving considerable attention. It has a short, sharp awn, and stiff bristles on palea and lemma. It threshes and cleans easily but is most difficult to seed through a grain drill. Processing polished the seed, removed most of the awns and bristles, and allowed it to flow easily through the grain drill.

Side-oats grama.—Side-oats grama (*Bouteloua curtipendula*) is awnless, but the five to eight spikelets are not deciduous from the rachilla, the whole spike falling together. The processing broke up the spike into individual spikelets and freed some caryopses. Recleaning removed empty glumes, rachilla joints, and empty spikelets. Processed seed used on about 5 acres has given a very even stand, the seeding being done with a four-row plate nursery seeder.

Green needle grass.—The awn in green needle grass (*Stipa viridula*) is about 50% deciduous in threshing. In addition to the awn, there are present fine white callus hairs which keep the seed from feeding into the drill cups. The processing removed all the awns, polished the

TABLE 2.—*Results of process on germination of seed within the first six months after processing.*

Species	Treatment	Germination, %*		
		Dec. 1, 1938	Feb. 1, 1939	Mar. 1, 1939
Andropogon furcatus (7 lots)	Untreated	40.3	40.0	30.0
	Treated†	48.0	38.7	48.6
	Caryopses‡	58.5	71.0	77.8
Bouteloua curtipendula (5 lots)	Treated†	53.0	60.5	65.5
	Caryopses‡	54.2	66.7	67.2
Bouteloua gracilis (3 lots)	Untreated	67.0	75.0	67.6
	Treated†	83.0	79.0	80.3
	Caryopses‡	82.5	84.6	80.3

*Seed processed in September and October.
†"Treated" defined as caryopsis with palea and lemma intact.
‡Caryopses freed from palea and lemma in processing.

[3]The use of "Russian wild-rye" as a common name for *Elymus junceus* is unofficial.

seed, and removed enough of the pubescence to allow the seed to slide easily in the drill. It was rough-cleaned over the fanning mill before polishing, and recleaned afterward.

The cost of this process is so low that it is not a factor in comparison to the improvement in quality of the seed. The loss of total weight in treating a lot of seed was very marked, but there was little actual loss of filled florets. There was, however, a possibility that some or all of the species would suffer a decrease in viability through the violence of the treatment. This was particularly true where caryopses were removed. Germination data indicate no change immediately after processing, and stored samples germinated throughout the winter showed no loss in viability of the cleaned caryopses six months after treatment.

The results shown in Table 2 are average figures for the larger lots handled. The three species shown are those in which caryopses are freed in the process and which would therefore be expected to show changes in germination. All germinations shown were made in soil in the greenhouse at an approximate soil temperature of 30° C.—G. L. WEBER, *Mandan, N. D.*

CHROMOSOME NUMBER IN DWARF OATS

A STUDY of the chromosome number of five varieties of dwarf oats is reported. These drawfs are known under the names Trelle, Denton, Prolific, Early White, and Early Black (C. I. Nos. 3634, 3635, 3636, 3637, and 3638, respectively).[1] They may be divided into two groups, as the Trelle and Denton dwarfs have short, abnormal, compact panicles with very thick, stiff, tough culms. The other three are true dwarf oats and have panicles and stems similar to those of normal oats, although shorter and smaller. Information on the origin, characters, etc., of these dwarfs appears in the literature.[2]

The desirability of using the Trelle and Denton dwarfs in crosses with varieties of normal stature for the purpose of deriving agronomic varieties of oats having stiffer straw and greater standing ability makes the determination of their chromosome number relevant. Attempts to cross these dwarfs on varieties of normal height thus far have been unsuccessful. Consequently specimens were collected for the writers at the Aberdeen Substation, Aberdeen, Idaho, by Harland Stevens and Ogden C. Riddle and forwarded to Washington for cytologic examination of the pollen mother cells by the senior writer.

In all five varieties 21 bivalent chromosomes were found at diakinesis. Fig. 1, A-D, shows the chromosomes in four of these five varieties. It was not unusual to find in some pollen mother cells chromosome abnormalities such as are shown in Fig. 2, B, E. These

[1]C. I. refers to accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.

[2]STANTON, T. R. Prolific and other dwarf oats. Jour. Heredity, 14:301–305. 1923.

————. Superior germ plasm in oats. U. S. D. A. Yearbook 1936:347–414. 1936.

DERICK, R. A. A new "dwarf" oat. Sci. Agr., 10:539–542. 1930.

ATKINS, I. M. and DUNKLE, P. B. A dwarf oat found in a Nortex-Victoria cross. Jour. Amer. Soc. Agron., 30:347–348. 1938.

two photo-micrographs illustrate the occasional failure of one or more chromosomes to be included within the metaphase plate. In the varieties Early White and Prolific such abnormalities seemed more prevalent than in the other three varieties. It is quite possible that

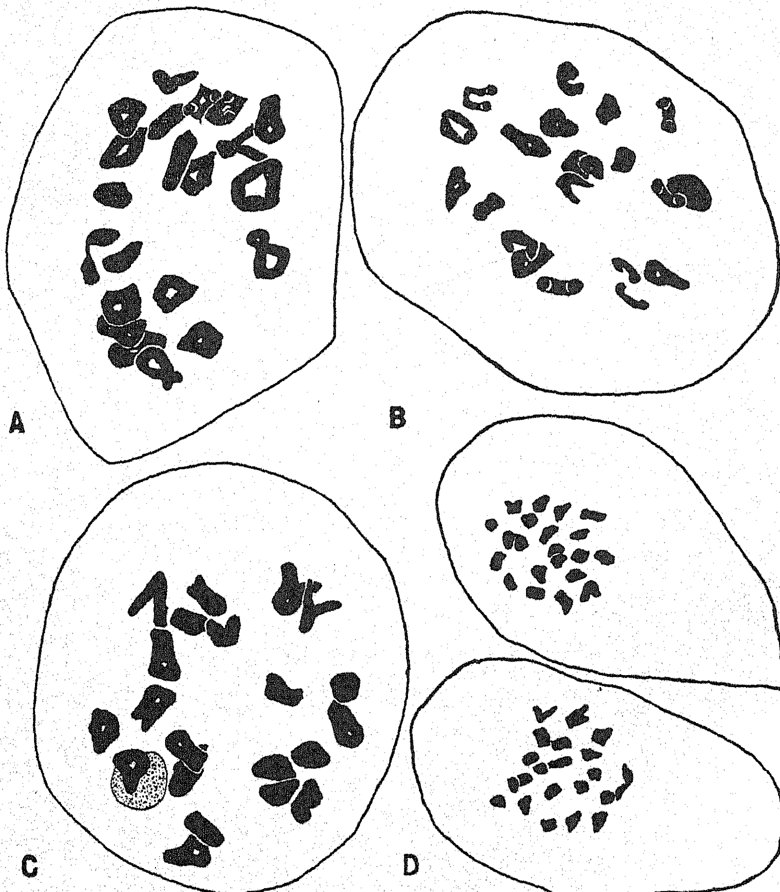

FIG. 1.—Chromosomes at reduction phases in the pollen mother cells of four dwarf oat varieties: A, diakinesis in Prolific dwarf; B, diakinesis in Trelle dwarf; C, diakinesis in Denton dwarf; D, second metaphases in Early Black dwarf.

these irregularities in meioses were due to an abnormal environment at the time the material was collected. The majority of the pollen mother cells in all five varieties distributed their chromosomes, in the reduction phases, equally to the daughter cells. Fig. 2, A, C, D, and F, shows several phases in which the chromosome behavior is normal.

In conclusion, no chromosomal incompatabilities appear to exist that might prevent hybridizing the Trelle and Denton dwarfs with oats of standard stature for the purpose of transferring their desirable

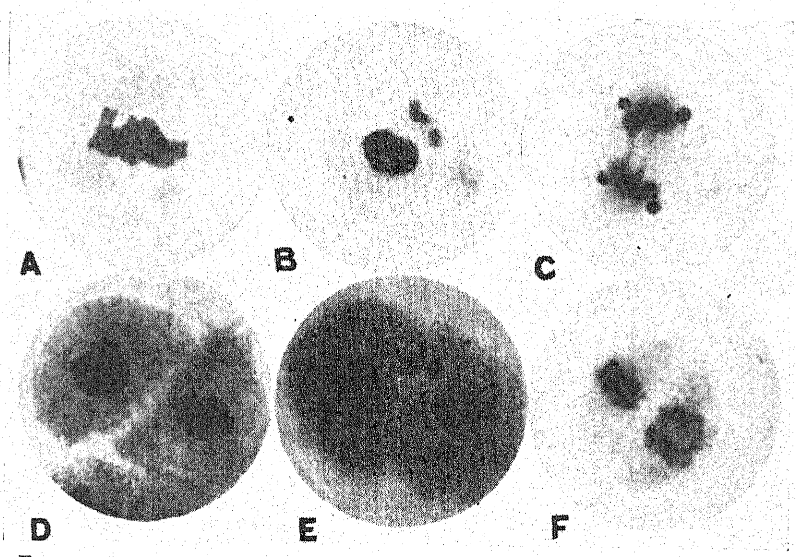

FIG. 2.—Photo-micrographs of normal and abnormal reduction phases in the pollen mother cells of dwarf oat varieties: A, normal first metaphase plate of Early Black dwarf; B, abnormal first metaphase plate of Prolific dwarf; C, normal first anaphase of Prolific dwarf; D, normal second division phases in Prolific dwarf; E, abnormal second metaphases in Prolific dwarf; F, normal second division phases in Early White dwarf.

straw characters to commercial varieties.—A. E. LONGLEY AND T. R. STANTON, *Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture.*

THE CROP-PRODUCING VALUE OF VETCH ROOTS[1]

VETCH is grown primarily to increase the yield of the corn or cotton crop which follows after turning under the vetch. The increase in yield of crops following vetch is due largely to the nitrogen taken out of the air by the vetch.

Experiments conducted at the Mississippi Agricultural Experiment Station show that the roots of vetch contain 35% of the nitrogen in the whole plant. In other words, if the entire tops of vetch are removed level with the top of the ground, more than one-third of the nitrogen which the vetch contains will be left in the soil.

The crop-producing value of vetch roots is shown by the following data:

	Yield of corn, bu. per acre
No vetch..................	15.9
Vetch turned under..........	33.1
Vetch with tops removed.....	23.3

[1]Contribution from the Department of Agronomy, Mississippi Agricultural Experiment Station, State College, Miss. Published with the approval of the Acting Director as Journal Article No. 20 N. S.

The vetch roots increased the yield of corn 7.4 bushels. Where the tops were also turned under an additional 9.8 bushels of corn were obtained. The test was conducted on Ruston fine sandy loam. The plats were 1/35 acre in size, and there were nine replications.

In this test the vetch was scraped off with a hoe and all of the tops removed. Where vetch is cut for hay, some of the tops will be left on the ground and, on the basis of the data presented, these tops together with the roots will probably increase the yield of corn a little better than half as much as where the whole vetch plant is turned under. In other words, cutting vetch for hay will leave half of its crop-producing value in and on the soil for corn production.

Similar or better results can probably be obtained when the vetch is grazed off by livestock as when cut for hay.—W. B. ANDREWS, *Agricultural Experiment Station, State College, Miss.*

A SAMPLER FOR SURFACE SOILS

IN taking samples of surface soil for moisture determination or for chemical analysis it is desirable to take a uniform core of soil from the surface to a given depth. In cultivated soils this is impossible with an auger because the dry soil at the surface falls away and the resulting core is not representative of the surface soil as it existed in the field. Samples obtained with a spade are too large to handle, and if an aliquot is taken, a serious error may result from improper mixing before taking the aliquot.

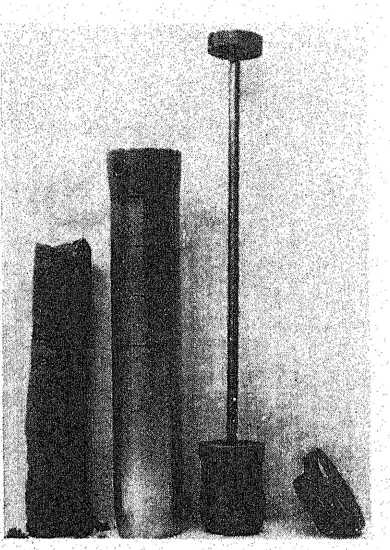

FIG. 1.—A sampler for surface soils. The core drops out readily when the tube is inverted.

A tubular sampler seems to be the best tool for this purpose and many such samplers have been described in the literature. The sampler herein described varies from the usual tubular type in that the bore is not uniform throughout. This arrangement eliminates some of the difficulties encountered with the uniform bore sampler.

In a tubular sampler of uniform bore the friction on the walls causes a compaction in the core which tends to push the core downward instead of cutting it cleanly and without disturbance. Errors in sampling are thus introduced. Furthermore it is difficult to remove the core from such a tube. This difficulty has been only partially overcome by cutting a slot in the side of the tube for a portion of the length. This arrangement has a disadvantage in that it weakens the tube.

The sampler illustrated in Figs. 1 and 2 was made from a 1¾ by 8 inch steel shaft. The first step was to drill a 1¼ inch hole through the center of the shaft. Next the bore was increased to $1\frac{5}{16}$ inches from the top to within ½ inch of the bottom of the tube. By means of a still larger drill the bore was then increased to $1\frac{11}{32}$ inches for a distance of 4⅜ inches from the top of the tube. The outside walls were then turned down to the dimensions shown in Fig. 2. Calibrations 1 inch apart were placed on the outside of the sampler to make it possible to take samples to a uniform depth. A ¼-inch hole was drilled through the top. A rod passed through this hole makes it easy to turn the tube as it is forced into the soil.

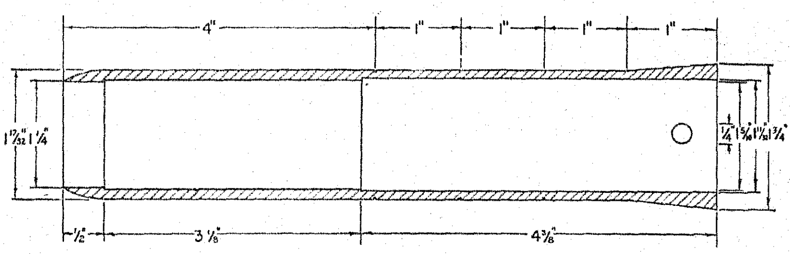

FIG. 2.—Sectional diagram of surface soil sampler.

This sampler, constructed as described, has proved to be very durable. Fine-textured soils have been sampled when they were so dry that the sampler had to be driven into the soil by means of a hammer. The driving cap shown in Fig. 1 was made for this purpose. The heavier wall in the upper 1 inch of the tube was found to be necessary to avoid injury to the tube when being driven into dry soil. The lower end of the tube, turned down to form a cutting edge was tempered slightly.

When the sampler is turned or driven into the soil the core is not depressed and, except in the case of wet clay soils, it drops out readily when the tube is inverted. The plunger shown in Fig. 1 was designed to aid in removing the core from the sampler, but it is only required when the soil is wet and very sticky. The ease with which the core may be removed makes it possible to take a large number of samples in a short time.—R. L. COOK AND B. J. BIRDSALL, *Michigan State College, East Lansing, Mich.*

WEATHER IN RELATION TO YIELD OF AMERICAN-EGYPTIAN COTTON IN ARIZONA[1]

IN studies incidental to a survey of production trends of American-Egyptian cotton the annual fluctuations in yields of this extra long staple cotton were compared with maximum, minimum, and average temperatures, with percentages of relative humidity, with dates of killing frost, and with evaporation. Of these six weather phenomena only date of killing frost and evaporation showed any consistent relationship with yield.

[1]Contribution from the Division of Cotton and Other Fiber Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture.

The final yield of cotton is undoubtedly affected by complex interactions of many weather factors. The indirect effects of weather on cotton yields may be almost as important as the direct effects by favoring, or retarding, the reproduction of harmful insects and the progress of diseases. Also, soil fertility, amount of irrigation water used, method or time of irrigation, insect damage, plant diseases, and frequency of picking are all factors that affect yield. When comparing one weather factor with yield a high correlation can not be expected because one or more of the other factors affecting yield may be counteracting the effects of the phenomenon under consideration.

The length of the growing season is distinctly one of the limiting factors in the production of high yields of Pima cotton in Arizona. Fig. 1 shows the number of days from September 30 to killing frost at Sacaton, Arizona, in comparison with the average yields of American-Egyptian cotton in Arizona from 1918 to 1938, inclusive. The chart shows that in seasons when frosts are early yields are low, and in years when frosts are late yields are high, with very few exceptions to the general trend.

Evaporation is the result of several interacting weather factors, namely, temperature, wind velocity, atmospheric humidity, and sunshine. Fig. 2 shows the average annual yields of American-Egyptian cotton for the 21 years from 1918 to 1938 in comparison with the total evaporation for the months of July and August. Evaporation was measured at Sacaton in an open tank of the type used for many years

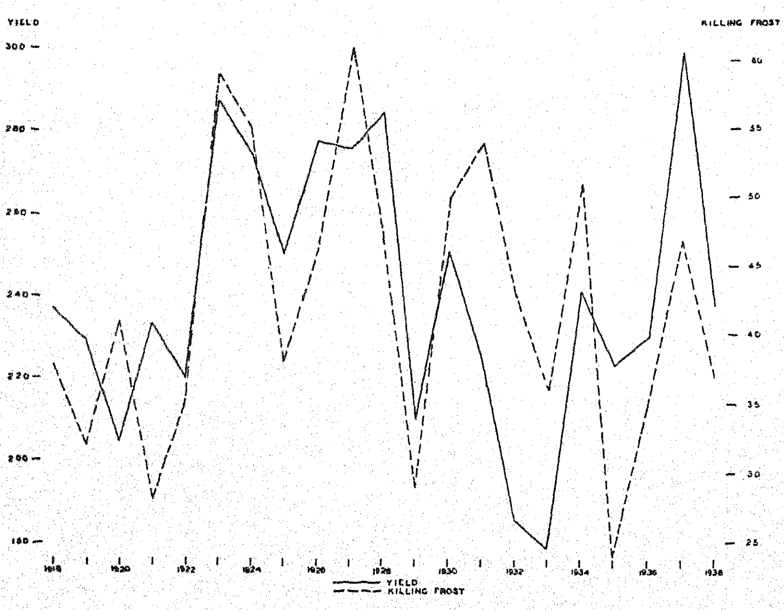

FIG. 1.—Yields per acre, in pounds of lint, of American-Egyptian cotton for Arizona and number of days from September 30 to the first killing frost at Sacaton, Arizona, for the years 1918–1938, inclusive. The value of the correlation coefficient, +.574, is above the 1% level of significance.

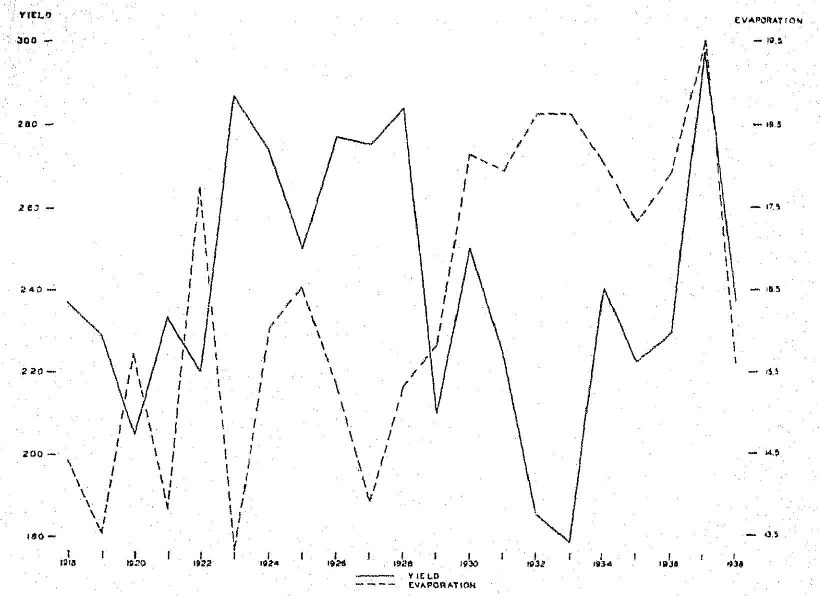

FIG. 2.—Yields per acre, in pounds of lint, of American-Egyptian cotton for Arizona and evaporation, in inches, during July and August from an open tank at Sacaton, Arizona, for the years 1918–1938, inclusive. The value of the correlation coefficient, −.296, is not significant. When the data for the very exceptional season of 1937 are excluded, the value of the correlation coefficient for the remaining 20 comparisons is raised to −.562, which is on the 1% level of significance.

at stations of the Bureau of Plant Industry. The months of July and August cover practically all of the effective flowering period of Pima cotton in Arizona.

In some districts a crop of Pima cotton is grown with as little as 4 acre feet (48 acre inches) of irrigation water, including that applied at planting time. The average July and August evaporation for these 21 years is 16.3 inches, or approximately one-third of the amount of water some farmers use in the entire growing season. In 1931, 1932, 1933, and 1937 evaporation in July and August averaged 18.6 inches. With the exception of 1937 the average yield in each of these years was much below the 21-year average. The correlation of yield with evaporation during flowering period for the 21 available comparisons is so low that it has no statistical significance. On the other hand, when the data for the very exceptional season of 1937 are excluded, the data for the remaining 20 years give an r of −.562, a highly significant negative correlation. A value of −.809 is obtained for a partial correlation of yield with evaporation (frost constant) for the same 20 years.

Assuming that the factors promoting excessive evaporation during the flowering period also tend to reduce the yields of cotton, it seems reasonable to believe that heavier or more frequent irrigations may

counteract, at least in part, the ill effects of these factors. However, if irrigation water in excess of the optimum is applied the ill effects of over-irrigation might entirely offset the benefits to be derived from the practice of increasing irrigations during seasons of excessive evaporation.

In conclusion, data are presented which show that early killing frost in the fall and high evaporation during the flowering period are two of the weather factors which appear to limit yields of American-Egyptian cotton in Arizona. Increased irrigation during the critical flowering period, within reasonable limits, is suggested as a means of counteracting the effects associated with high evaporation.—H. J. FULTON, *U. S. Field Station, Sacaton, Arizona.*

AGRONOMIC AFFAIRS

CALIBRATING QUICK CHEMICAL SOIL TESTS

THE Soil Testing Subcommittee of the Fertilizer Committee of the American Society of Agronomy has assembled a series of 30 soils from 15 states for the purpose of calibrating the results of quick chemical tests by various methods.

These soils have been stored at the laboratory of the Division of Soil Chemistry and Physics, Bureau of Plant Industry, U. S. Dept. of Agriculture, Washington, D. C. Sets of small sub-samples of these soils will be supplied to persons engaged in research on the development or comparative study of soil testing methods.

Requests should be addressed to Dr. H. G. Byers, Division of Soil Chemistry and Physics, Bureau of Plant Industry, U. S. Dept. of Agriculture, Washington, D. C.

EXTENSION SERVICE FILM STRIP

A CONTRACT for film strip production for the Extension Service of the U. S. Dept. of Agriculture has been awarded for the fiscal year 1939–40. Prices for film strip will range from 50 to 75 cents each, with the majority of the 325 series offered by the Department selling for 50 or 55 cents each. A price list of avaliable strips and instructions on how to purchase them may be obtained by writing to the Extension Service in Washington, D. C.

Film strips are available on such subjects as soil conservation, farm crops, dairying, farm animals, farm forestry, plant and animal diseases and pests, roads, farm economics, farm engineering, home economics, adult and junior extension work, and rural electrification. Lecture notes are provided with each film strip purchased, with the exception of those that are self-explanatory.

NEWS ITEMS

JERRY H. MOORE, cotton technologist for the North Carolina Agricultural Experiment Station, was awarded the degree of doctor of philosophy by Duke University last spring. Doctor Moore majored

in genetics and plant breeding and part of his graduate study was carried on at Cornell University.

DR. FRANKLIN S. HARRIS, President of Brigham Young University, has been given a leave of absence to accept a commission of the Government of Iran to reorganize the Department of Agriculture of that Government and to lay plans for the rehabilitation of the agriculture of the country. During Doctor Harris' absence, Dr. Christen Jensen, Dean of the Graduate School, will serve as Acting President of Brigham Young University.

DR. D. W. THORNE, until recently Associate Professor of Soils at the Texas A. and M. College, has been appointed to a similar position at the Utah State Agricultural College and Experiment Station. In his new position, Doctor Thorne will divide his time about equally between teaching and research in soils.

DR. LEONARD H. POLLARD has been appointed Assistant Professor of Vegetable Crops at the Utah State Agricultural College and Experiment Station where he will teach the work in vegetable crops and do research in vegetable crop production and genetics. Doctor Pollard was formerly associated with the University of California at Davis where he served as Associate in Vegetable Crops and where he recently completed work for the doctorate degree in genetics.

DR. A. E. BRANDT, Senior Statistical Analyst and also Acting Chief of the Division of Soil and Water Conservation Experiment Stations for the Soil Conservation Service in Washington, is spending the first summer session at the Utah State Agricultural College where he is teaching courses in statistics and in the design of experiments. Doctor Brandt is also conducting informal conferences with Experiment Station staff members in the design of experiments and in the analysis of experimental data.

DR. R. D. LEWIS whose major activities have recently been in extension and resident teaching at Ohio State University, has been appointed to a full time teaching-research position with the titles of Professor of Agronomy in the University and Associate in Agronomy in the Ohio Agricultural Experiment Station. In the absence of Doctor Salter, Chief of the Agronomy Department of the Experiment Station at Wooster and Chairman of the Department of Agronomy at Ohio State University, Doctor Lewis will serve as Vice-Chairman of the College Department. In addition to present teaching duties he will be responsible for the Department's program of instruction in crop genetics and breeding with major emphasis upon development in the graduate area. For the Experiment Station he will direct and supervise certain phases of the crops breeding program and will continue to give attention to problems dealing with the practical utilization of the output of crops breeding programs.

DAVID F. BEARD, for the past three years graduate fellow in agronomy and assistant secretary-treasurer of the Ohio Seed Improvement Association, has been appointed Extension Agronomist

to succeed Doctor Lewis. Mr. Beard has also been elected to replace him as Secretary-Treasurer of the Ohio Seed Improvement Association.

DR. E. G. BAYFIELD, formerly Cereal Technologist, U. S. Dept. of Agriculture, in charge of the Federal Soft Wheat Laboratory, and Associate in Agronomy, Ohio Agricultural Experiment Station, has recently taken up his duties as Head of the Department of Milling Industry, Kansas State College, Manhattan, Kansas.

DR. OLAF S. AAMODT, formerly head of the Department of Agronomy at the University of Wisconsin, has been named Principal Agronomist in charge of the Division of Forage Crops and Diseases of the U. S. Dept. of Agriculture to fill the position vacated by Dr. P. V. Cardon, recently named assistant chief of the Bureau of Plant Industry. In his new position Dr. Aamodt will direct all federal research on the production and improvement of forage plants throughout the United States and will have general supervision of the Northeastern Regional Pasture Laboratory at State College, Pa.

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MAIZE SEED CHARACTERS IN RELATION TO HYBRID VIGOR[1]

MORRIS E. PADDICK AND HOWARD B. SPRAGUE[2]

BECAUSE selected strains of hybrid corn are playing an increasingly important role in crop production, papers dealing with the maize kernel and its parts have been frequent. Some have been concerned with the effect of heterosis on the grain itself, others in explaining hybrid vigor through differences in embryo characteristics, such as size and amount of meristematic material. The study herein reported had as its purpose the prediction of high- or low-yielding ability for a strain through measurement of some specific kernel characters.

Kiesselbach and Cook (5)[3] in 1924 published observances on the increase of kernel weight through stimulation by foreign pollen. They ascribed such increases to changes in endosperm composition and to heterosis. Then later Kiesselbach (4) reported that the gain was a matter of kernel competition where hybrid kernels became heavier at the expense of adjoining inbred kernels. Ashby (1, 2), from a study of heterosis, concluded that hybrid vigor was due to a greater weight of the embryo which gave an advantage maintained throughout the grand period of growth. He proposed that growth rate be considered a simple dominant character. Sprague (6), however, could find no correlation between embryo size and heterosis, and found that hybrids grew relatively faster than either of the parents. His investigations indicated no difference in the growth rates of reciprocal crosses, although there were decided differences in embryo size. He therefore held to the theory of complementary action of dominant growth genes. As further evidence negative to Ashby's hypothesis, Bindless (3) reported the apparent lack of correlation between size of plumular meristem, or of the size of the cell nuclei contained therein, and hybrid vigor.

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[3]Figures in parenthesis refer to "Literature Cited", p. 750.

MATERIAL AND METHODS

The seed material used in these studies was in part obtained from the New Jersey Experiment Station breeding stocks, but mostly from special crosses. In the latter case inbred lines characterized by white kernel endosperm were used as ear parents in crosses with lines carrying the factor for yellow endosperm. By using mixed pollen, one part of which was derived from the female parent plant, inbred as well as hybrid kernels were obtained on the same ear. Comparisons might thus be made between two germinal types, separation of the inbred from the hybrid seeds being possible through their color difference.

Kernel dissection was accomplished by soaking the grains in boiling water for approximately 5 minutes, removing the pericarp with a pair of tweezers, then splitting the kernel through the face and back, and finally digging out the germ with a dissecting needle. Kernel parts were dried at a temperature of 90° to 95° C for approximately 48 hours. To obtain weight means of desirable accuracy groups of 20 grains each were used. This number of kernels taken from each ear gave for the germ weight a mean with a probable error of less than 2%.

VARIABILITY IN KERNEL PARTS

Much variability was encountered in the weight of kernel parts, a portion of which could be ascribed to heredity effects, but a large amount of which was undoubtedly due to environment. Some appreciation of this problem may be gained by observing the data in Table 1. These illustrate the average weights of kernel parts as determined for the selfed line A55 and for the hybrids of which it was the ear parent. Forty adjoining kernels (20 inbred and 20 hybrid) were used for each of the hybrid-inbred kernel comparisons. So far as possible the grains for each comparison were obtained from a single ear.

Theoretically seeds which are genetically identical should show great uniformity. As the figures obtained for several lots of inbred kernels indicate, however, there were very decided differences from ear to ear and from season to season, not to mention from seed to seed.

Despite the disturbing effects of environment, differences which were due to heredity may be observed from the data of Table 1. In the percentage variability for the weight of germ, endosperm, and total seed, and especially for the endosperm-germ ratio, is this true. This may be confirmed by observing the coefficients of variability for the group of hybrids having A55 as maternal parent compared with the coefficients of the group of matched lots of A55 inbred kernels. The results are the same for both 1934 and 1935, although in the latter season poorer growing conditions caused the kernels to be smaller and less uniform.

For a summary, Table 2 may be referred to. Here nine hybrids are represented of which A55 was the ear parent and for eight of which B19 was the female parent. Likewise, nine groups of inbred A55 kernels and eight groups of inbred B19 kernels are also represented; each group having been formed from grains grown on the same ear and adjoining or close to those of the corresponding hybrid.

A basis was thus established for study of the various kernel parts and their interrelations in hybrids and inbreds. The object was to determine if any part, directly or indirectly, influenced the grain-

TABLE I.—*Comparison of kernel parts of an inbred line of corn and hybrids from it.**

Strain	1934 Pericarp	1934 Endosperm	1934 Germ	1934 Total weight	1934 Endosperm-germ ratio	1935 Pericarp	1935 Endosperm	1935 Germ	1935 Total weight	1935 Endosperm-germ ratio
	Dry weight in mgms, average of 20 grains									
Hybrids										
A55×A2	19.7	351.1	40.3	411.2	8.7	—	—	—	—	—
A55×A5	19.1	325.0	36.9	381.0	8.8	17.4	211.9	19.4	248.7	10.9
A55×A11	19.6	366.1	37.9	423.7	9.7	18.6	250.7	24.0	293.0	10.4
A55×A12	19.8	362.2	40.2	422.2	9.0	18.4	267.7	26.3	312.4	10.2
A55×A15	19.6	342.2	40.1	402.0	8.5	19.0	237.4	22.8	279.3	10.4
A55×A25	17.6	317.0	32.3	366.9	9.8	—	—	—	—	—
A55×A30	19.3	320.1	35.2	374.6	9.1	14.0	210.8	17.2	242.0	12.2
A55×A32	20.6	371.2	37.5	429.9	9.9	—	—	—	—	—
A55×A47	18.6	329.7	33.7	382.0	9.8	—	—	—	—	—
Mean. . .	19.3	342.8	37.1	399.3	9.25	17.5	235.5	22.0	275.1	10.8
S. D. . . .	0.8	20.9	2.9	23.7	0.59	2.0	24.3	3.6	29.6	0.81
C. V., %	4	6	8	6	6	12	10	17	11	7.5
A55 Inbred Kernels Paired With Hybrid										
A55 (A2)	17.0	242.1	26.6	285.7	9.1	—	—	—	—	—
A55 (A5)	16.5	256.2	29.4	302.2	8.7	16.8	157.3	16.4	190.5	9.6
A55 (A11)	19.1	260.2	28.5	307.8	9.1	15.4	162.0	18.2	195.7	8.9
A55 (A12)	18.0	255.7	29.4	303.2	8.7	14.9	165.8	17.8	198.5	9.3
A55 (A15)	17.3	255.7	29.7	302.7	8.6	17.5	172.4	17.6	207.5	9.7
A55 (A25)	15.3	222.2	25.9	263.4	8.6	—	—	—	—	—
A55 (A30)	18.7	239.2	28.8	286.7	8.3	12.5	134.1	14.7	161.4	9.1
A55 (A32)	18.5	256.0	29.1	303.7	8.8	—	—	—	—	—
A55 (A47)	17.6	264.1	30.1	311.8	8.8	—	—	—	—	—
Mean. . .	17.5	250.1	28.1	296.4	8.75	15.4	158.3	16.9	190.6	9.3
S. D. . . .	1.2	13.2	1.4	15.1	0.25	1.9	14.6	1.4	17.5	0.33
C. V., %	7	5	5	5	3	12	9	9	9	4

*Determinations made on paired inbred and hybrid kernels from the same ear.
†Indicates the hybrid with which A55 kernels were paired as: A55 (A2) with A55×A2.

TABLE 2.—*Coefficients of variability for the means of the groups with each group composed of 20 kernels, 1934.*

No. of groups	Strain	Pericarp	Endo-sperm	Germ	Germ-endo-sperm ratio
9	A55 selfs	7	3	5	3
9	A55 hybrids	5	6	8	6
8	B19 selfs	18	14	9	8
8	B19 hybrids	16	16	11	12

or stover-yielding ability of a genetic line. The investigation logically resolved itself into two angles of attack, *viz.*, the significance of absolute size as measured by weight and of relative size when compared to values obtained for the female inbred line—the ear parent. Ashby's hypothesis of hybrid vigor in maize placed emphasis on the size of the embryo in the seed as an important factor, like the capital to which compound interest rate is to be applied. But even on casual observations this theory is subject to difficulties. Great uniformity of characters is the essence of a "pure" line, inbred or hybrid, and for all practical purposes the same may be said regarding reciprocal crosses. However, the individual kernels of a specific line may vary greatly in size, depending on their position on the ear, the particular maternal plant, and the seasonal environment. Even more marked may be the difference in size between the kernels of reciprocal crosses.

In view of the previously noted variability in average germ size between seed sample groups of the same line, it was considered desirable to investigate the correlation of germ weight with kernel weight. Let one assume germ size to have important direct influences on the future possibilities of the plant, such as grain and stover yields. Then observed uniformity of mature plants should follow from size uniformity of seed embryos themselves regardless of the total kernel weight. To test this supposition kernels of two strains of corn, one an open-pollinated variety, Lancaster Surecrop, and another a double cross (B42×A64)×(A30×A47), were sorted into air-dry weight groups 20 mgms apart. Kernel dissections were made and the endosperm and germ weights for each determined. The size relationships between the kernel parts are graphically shown in Fig. 1. There is no doubt that the germ tends to constitute a definite proportion of the total kernel weight, regardless of the seed size.

However, it must be admitted that for any given line the majority of the kernels will not deviate far from their mean weight, and thus the effects of extreme kernel size will not be apparent in the field. Since plat test yields are the averages of many plants in which the variability of the individual is lost, there is really no secure basis for assuming that embryo size does not have its effect. The writers know of no experiment designed especially to determine the relationship between embryo size and plant yield.

A more tangible means of ascertaining embryo size effect is through the comparison of reciprocal crosses. For all practical purposes the members of such a pair are genetically identical, and it is generally

assumed there is little difference at maturity. Any significant difference between the kernel embryo size of the two crosses would therefore discredit this seed part of any important influence on plant growth.

The data of Sprague (6) induce this conclusion. In one instance he was able to vary embryo size in a line through the harvesting of seed at various stages of maturity, but found no significant differences in plant growth rate. Furthermore, he checked the growth rate of plants of reciprocal crosses where there was a significant difference in average embryo size, and again found no correlation between embryo weight and growth rate.

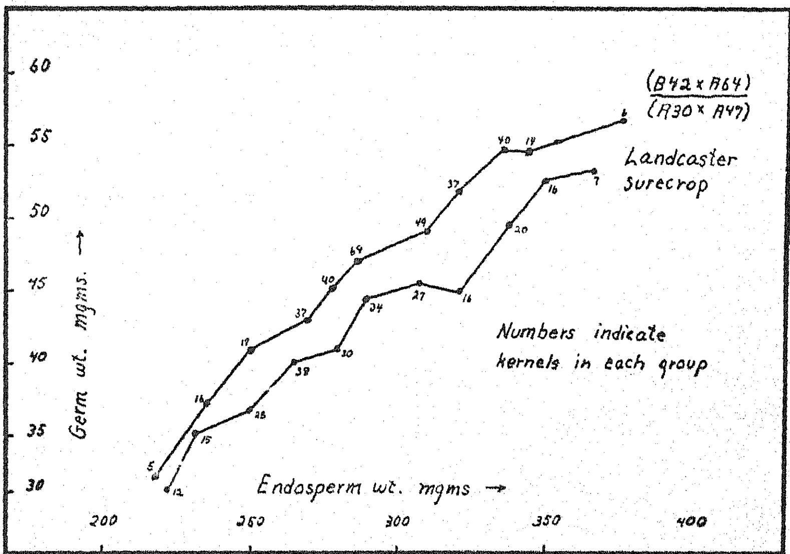

FIG. 1.—Dry weight relation of germ to endosperm in kernels of the same strain.

In Table 3 will be found data on the kernel part weights for inbred lines and their reciprocal crosses, of which A55 is one parent. Of principal interest and significance, in accord with the foregoing conclusions, will be noted the marked variation in germ weight between the members of a reciprocal cross, although the genotype remains identical.

STIMULATION OF EMBRYO AND PLANT YIELD

The possibility of a direct relationship between embryo size and plant growth is not favored by the preceding data and by the data of others. Environmental conditions, especially the nutrition of the developing seed, have a highly significant role in determining the size of the kernel and its parts. The corn germ may perhaps best be considered as a transition stage in the growth of the plant, a necessary

TABLE 3.—*Seed part weights of reciprocal crosses and their parents, averages of 20 kernels.*

Strain	Pericarp, mgms	Endosperm, mgms	Germ, mgms	Percentage difference*	Endosperm-germ ratio
A55 selfed	17.5	250.1	28.1		8.75
A55×A2	19.7	351.1	40.3		8.7
A2×A55	5.2	123.5	15.2	90.6	8.1
A2 selfed	9.2	225.1	30.6		7.3
A55×A5	19.1	325.0	36.9		8.8
A5×A55	12.8	184.8	21.8	51.6	8.5
A5 selfed	21.4	276.1	31.9		8.6
A55×A9	18.0	267.2	30.8	23.2	8.7
A9×A55	9.8	180.1	24.4		7.4
A9 selfed	11.5	186.2	25.7		7.2
A55×All	19.6	366.1	37.9	35.8	9.7
All×A55	15.3	229.7	26.4		8.7
All selfed	17.6	227.0	24.4		9.3
A55×A12	19.8	362.2	40.2	13.8	9.0
A12×A55	13.5	245.9	35.0		7.0
A12 selfed	13.6	182.8	36.0		6.6
A55×A15	19.6	342.2	40.1	25.6	8.5
A15×A55	12.7	231.5	31.0		7.5
A15 selfed	12.6	192.9	28.1		6.5
A55×A25	17.6	317.0	32.3	32.3	9.8
A25×A55	14.0	208.0	23.3		8.9
A25 selfed	14.3	197.8	32.2		6.1
A55×A30	19.3	320.1	35.2	8.3	9.1
A30×A55	25.5	301.5	32.4		9.3
A30 selfed	23.7	244.9	24.7		9.9
A55×A32	20.6	371.2	37.5	36.3	9.9
A32×A55	10.7	237.0	26.0		9.1
A32 selfed	12.0	240.2	24.1		10.0
A55×A47	18.6	329.7	33.7	10.9	9.8
A47×A55	14.9	224.6	30.2		7.4
A47 selfed	13.1	194.2	26.6		7.3
Lancaster Surecrop	23.6	281.5	41.0		6.9

*Germ weight difference between reciprocals as % of their average.

suspension of activities in the change from one environment (on the ear) to another (in the soil).

It is to be remembered, however, that the hybrid or inbred plant comes into being with the fusion of the parental gametes to form a zygote. Hybrid vigor then is to be expected as much in the development of the embryo as in the plant following germination. Growing side by side in nearly identical environment (on the parental ear), hybrid kernels with their 2n germ and 3n endosperm should best

their inbred relatives in the struggle for nutriment—as do plants in the field.

There is then to be considered the significance of correlation between the stimulatory effect of cross fertilization on the corn kernel embryo and the potentialities of the hybrid plant produced. By stimulatory effect is meant the increase in germ and endosperm weight of hybrid kernels over inbred kernels borne on the same ear, as illustrated in Table 4.

TABLE 4.—*Weights of hybrid kernel parts in percentages of the maternal inbreds when grown on the same ear with groups of 20 kernels each, 1934.*

No. of groups	Strain	Pericarp, %	Endosperm, %	Germ, %
9	A55 hybrids	110.4 ±1.7	137.1 ±2.6	129.7 ±3.7
3	B8 hybrids	100.6 ±1.4	106.9 ±4.4	108.0 ±1.4
4	B16 hybrids	100.5 ±5.0	118.2 ±3.8	120.2 ±5.0
3	B18 hybrids	108.6 ±3.0	117.6 ±9.3	142.5 ±21.8
8	B19 hybrids	113.5 ±10.1	140.7 ±7.4	149.0 ±4.0

To test the possibility of using degree of embryo stimulation as an indicator of strain yield in stover and grain, a correlation coefficient was determined. The percentage germ weight increase of hybrid kernels over inbred kernels developed on the same ear was taken as one variable. Grain and stover yields as percentage of a check variety were used as the other variables. A number of such inbred-hybrid paired groups were used, representing crosses made on five inbred ear parent lines. The results are as follows:

Correlation	Year and pairs correlated 1934 (24)	1935 (22)
Germ increase with grain yield	.42	.36
Germ increase with stover yield	−.12	−.12
r value at 5% level of significance	.404	.42

Such a comparison as this is theoretically justified on the grounds that in all likelihood many of the plant characteristics which enter into the phenomena known as hybrid vigor are of an intangible and unmeasurable nature. Rates of reaction, sequence of processes, and balance of material distribution are perhaps all decisive factors in determining the adaptations and potentialities of the plant. Measurements of an indirect nature must be made through direct comparison of the total plants themselves, judging one in terms of another.

Comparing the kernel development of inbred and hybrid seed on the same ear is a measurement of this nature at a very early stage.

Admittedly there is a handicap in having to use the same maternal parent in all hybrids to be compared and thus not being able to compare unrelated lines. However, this method does offer a means for studying lines during their earliest period of growth, from zygote to embryo, a stage in which little has as yet been done.

SUMMARY

The pollen parent seems to be able to exert some influence on the weight of both corn kernel germ and endosperm and the ratio between the two. The general effect of outbreeding on the kernel is size stimulation.

Germ size in reciprocal hybrid kernels may vary greatly despite uniformity of mature plants, tending to substantiate Sprague's views on Ashby's hypothesis that embryo size is not a significant factor in the induction of hybrid vigor.

The ratio of endosperm-germ weight within a specific line remains relatively constant regardless of kernel size.

There seems to be no correlation between weight increase of hybrid kernel germ over that of the ear parent, when borne on the same ear, and forage-yielding ability. There seems to be a barely significant correlation (r equals approx. .39) between this germ weight increase and grain-yielding ability of hybrid strains.

The technic of producing hybrid kernels on the same ear as their maternal inbreds is suggested as a means of studying the development of hybrids in the period between the formation of the zygote and the maturity of the embryo.

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BIOCHEMICAL APPROACH TO GRASS PROBLEMS[1]

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IN its biochemical aspects, as in others, the pasture problem is a peculiarly complex one. Most studies in crop production and crop quality are concerned with the yield and composition of a certain part of the plant, grain or root, at maturity, the plant having been allowed to develop normally from the seedling stage to ripeness. High yields of mature material are not necessarily what we require of grassland, but instead a steady yield of immature material that shall be of high digestibility and nutritive value. The growth of the herbage may be checked by grazing or accelerated by fertilizer applications, and at the same time the botanical composition of the pasture may be radically altered. Therefore one is not dealing with a simple cycle of growth changes, but a sequence of superimposed effects not necessarily in phase. Pasture work in this respect bears to ordinary crop production studies the same sort of relationship that soil population studies bear to conventional pure cultural microbiology. It is often difficult to plan pasture experiments in which the chief factors are under control without laying the whole experiment open to the criticism of being highly artificial. To give only one example, there is the thorny point as to whether mowing as frequently practiced in experimental work is really equivalent to grazing by animals.

The purpose of a pasture is to produce feed that is of high quality. The aim of the biochemist is to be able to determine analytically the composition of the herbage in order that its value to the animal may be assessed and the consequences of particular management practices determined. The animal requires primarily a source of energy and secondarily certain specific and essential nutrients for body maintenance and growth. In the latter division fall the proteins contributing vital amino acids, the mineral constituents, and vitamins. There are fashions in research as in other fields, and much of the biochemical work on forage crops in recent years has been concerned quantitatively with minor constituents, such as the mineral constituents, carotene, and the vitamins, and lately also with essential amino acids. There seems to be, however, a regrettable tendency in considering the quality of grass to look chiefly at the nitrogen content and to imply that young grass is so much better than mature hay simply because of the higher content of protein it contains. Beasts do not live by protein alone, and even in the best grass the protein is a relatively small part of the whole. There appears then to be a real need for a further study of the energy-supplying constituents, which together comprise by far the greatest proportion of feeds, an examination of their relative availabilities, the prediction of their digestibility, and the study of management practices that will maintain a profitable compromise between yield and quality. This means that it

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will be necessary first to break down some of the complex pasture problems into simpler units which may separately appear not to be very practical, but which taken together should give what is wanted. The changing composition of the plant with age, the effect of fertilizers, and management, all ought to be determined independently first.

In the general question of digestibility there is no matter more important than the nature of those plant constituents, largely carbohydrate in nature, that supply the animal with energy. The field has somehow been neglected, perhaps because the necessary analytical methods have not been available. The main difficulty is that, in general, the properties of these substances are not clearly and sharply defined, so that the convenient solution and reprecipitation methods of inorganic chemistry are not applicable and recourse has to be had to procedures that aim at excluding other constituents and leave the required substance as a residue. The conventional system of analysis used for forage crops divides the carbohydrates quite empirically into two groups, "crude fibre" and "nitrogen-free extractives", the latter being obtained only by difference from 100 when other analyses have been totaled up.

Crude fibre is commonly pictured as being the fibrous, poorly digested, relatively unavailable part of the feed and the "N-free extractives" the easily digestible carbohydrates. This belief is firmly held and often expressed. Carefully conducted digestibility trials, however, not infrequently show (2)[3] the coefficient of digestibility of the "crude fibre" to equal that of the "nitrogen-free extract." Further, a consideration of the properties of the structural constituents that are presumed to be poorly digested and to be represented in the crude fibre fraction shows that they are likely to be very inadequately recovered in it. The chief structural constituents are cellulose, the polyuronide hemicelluloses, and lignin, but analyses of the crude fibre fraction from a number of forage crops have shown that it usually consists only of a portion of the cellulose, generally 60 to 80%, mixed with a small and very variable amount of lignin (4).

The proportions of the cellulose and lignin that are recovered vary so much even on the same type of material that the crude fibre fraction is not a reliable index of developmental changes in composition. It would be an important advance if the determination of the crude fibre fraction and its use in expressing composition were abandoned as inadequate, unreliable, and misleading. The most serious criticism of the present system of analyses used for grasses and forage crops is that there is included no measure of the lignin content. The concensus of opinion is that lignin is almost wholly unavailable to herbivorous animals, though in point of fact the data available on this point are extremely scanty. Experiments in which the fate of isolated lignin added to the diet is determined (3, 7), are not conclusive since the biological availability of lignin is known to be affected by the processes of isolation (5).

However, Crampton and Maynard (2) recently showed that 98% of the lignin in mixed pasture herbage clipped at different dates

[3]Figures in parenthesis refer to "Literature Cited", p. 760.

through the season could be recovered in the faeces of rabbits and approximately the same amount in that of a steer. Cellulose, on the other hand, though not directly digested by the animal is made available as a result of bacterial action in the rumen and intestine, and pure cellulose was long ago calculated to have a high "starch equivalent," which is to say that its energy is nearly as available as that of starch. The cell walls of young tissues are primarily cellulosic but as the tissue develops and the wall thickens lignin and hemicelluloses are deposited along with newly formed cellulose, encrusting and infiltering the cellulosic fabric to give inter-penetrating systems. The presence of lignin retards and prevents the bacterial degradation of the cellulose, probably largely through mechanical action. Deposition of lignin is more or less progressive with age and in general digestibility diminishes with age, but there comes a critical point beyond which cellulose availability is relatively small. The effect of the presence of lignin is not only to reduce the utilization of the cellulose but unless the feed is ground very fine, access of digestive juices to cell contents such as protein and more available carbohydrate is also hindered. As a result it is probably true to say that the degree of lignification of any normal forage crop affects its digestibility more directly than any other factor. Exactly how the degree of lignification may best be expressed has not been determined. The ratio of lignin content to cellulose content may prove to be more adequate than simple lignin percentage. This has not yet been tested by digestibility studies but is the logical probability from the arguments above.

The present system of analyses includes no measure of the lignin except insofar as the deposition of lignin is parelleled by the deposition of cellulose, part of which is represented in the crude fibre fraction. Even worse, the lignin is in fact included as an available constituent in the "nitrogen-free extractives" figure obtained by difference. This lengthy preamble is the case for the direct determination of cellulose and lignin as a minimum requirement in studies of pasture herbage composition. In addition it would be desirable that an attempt should be made to separate the other major carbohydrates, both structural and reserve, in order that the percentage of material unaccounted for shall be as small as possible, and not a composite of errors in method and technic as at present.

As illustrating the use of these newer analytical procedures and the breakdown of the pasture problem into the equivalent of pure cultural studies, the following experiments on the changing composition of grasses with age and fertilizer treatment might be quoted. These experiments were carried out at the Rothamsted Experiment Station in the seasons of 1935, 1936, and 1937 and the grasses concerned were rye grass (*Lolium italicium*), an annual variety known as Western wolths, and cocksfoot[4] (*Dactylis glomerata*). These were chosen as being some way apart on the scale of palatability. In the first season it was found that the cold water extract of immature rye grass was astonishingly high, approaching 50% in young samples. A portion of this was nitrogenous, of course, but the remainder to a considerable extent was found to consist of a fructose polysaccharide that may be

[4]Known in the United States as orchard grass.

described as fructosan or levan. The presence of fructose polysaccharides in members of the Gramineae has been reported a number of times, under such names as graminin, or sinistrin, but the amounts present have been regarded as small. In young rye grass at one stage more than one-third of the dry weight was fructosan, the percentage of which later decreased rapidly as maturity approached (Table 1).

TABLE 1.—*Fructosan in ryegrass, 1935.*

Sample No.	Date cut	Fructosan, %*
1	April 26	28.2
2	May 10	26.6
3	May 24	37.5
4	June 7	25.3
5	June 21	18.9

*Expressed as fructose after hydrolysis.

It is evident that this polysaccharide must be an important temporary carbohydrate reserve and must not be overlooked in digestibility studies, since at the time of peak content, it is quantitatively the major constituent of the grass. A similar fructosan has been found in young wheat and barley plants, the amount also falling rapidly as the ears form (1). The unexpected observation of the presence of this polysaccharide as a major constituent of young rye grass brings out another point that should be stressed, namely, that little is really known of the carbohydrate metabolism of grasses. Indications of the presence of a water-soluble glucose polysaccharide in comparatively small amounts were also obtained.

To obtain a detailed picture of the developmental changes in rye grass, composite weekly samples were taken from six plats each 1 square yard in size from early May to the end of July. This number of samples was insufficient for accurate yield data and in later experiments the number of plat samples was increased to eight. The grass was cut with shears, heated briefly at 100° C, and finally dried at about 35°. Soil nitrogen determinations were also made at each time of sampling. A selection of the analyses are given in Table 2, the full data being recorded by Norman and Richardson (6).

The nitrogen changes, here expressed for convenience as crude protein a practice that is probably almost as undesirable as the determination of crude fibre, were not unusual. The soil analyses showed that at all times there was a sufficiency of available nitrogen. The cellulose content appeared to increase steadily from 26% to 46%, though there was an indication in mid-June of rather more rapid deposition just about the time the heads were ripening. There was no increase in dry weight after the sixth or seventh sampling period, but nevertheless the cellulose content continued to rise, implying its formation from some other constituent (Fig. 1).

The lignin figures had a similar trend. Lignification is sometimes described as being a sudden and dramatic process ordinarily occurring when growth slackens toward maturity and accelerated particularly by drought or other unfavorable conditions. This hardly appears to be the case in grass, for the deposition of lignin took place steadily

TABLE 2.—*Yield and composition of rye grass (Western Wolths) expressed as percentage of oven-dry material.*

Sample No.	Date cut	Grams per sq. yd.	Crude protein, %	Cellulose, %	Lignin, %	Fructosan, %	Cellulose / Lignin
1	May 12	23	11.8	26.1	3.6	25.6	7.3
2	May 19	54	9.3	26.4	4.7	26.9	5.6
3	May 26	64	9.1	28.9	5.2	30.1	5.5
4	June 2	93	7.8	32.0	5.9	28.1	5.4
5	June 9	126	6.9	32.2	7.0	26.8	4.6
6	June 19	166	6.4	33.8	8.7	21.3	3.9
7	June 22	150	6.0	40.4	9.0	17.0	4.5
Hay*	June 22–29	—	5.6	43.2	10.4	11.8	4.2
8	June 30	161	5.4	38.3	9.1	14.7	4.2
9	July 7	161	4.7	39.9	9.6	12.6	4.2
10	July 14	165	4.7	43.2	10.5	7.0	4.1
11	July 20	151	4.2	47.1	11.2	5.7	4.2
12	July 26	126	5.0	46.2	11.1	3.2	4.2
13	Sept. 21	—	6.7	48.8	16.4	0.4	3.0

*This represents herbage cut on June 22 and allowed to dry in the field until June 29.

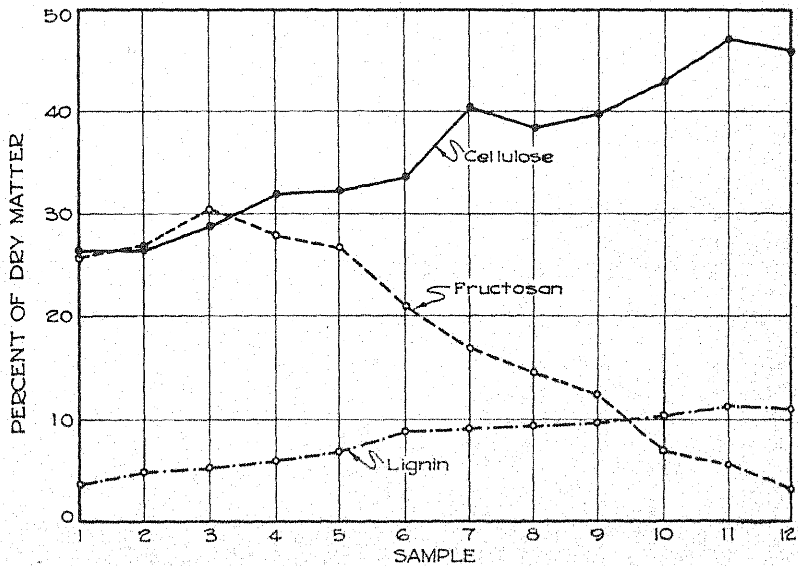

FIG. 1.—Changing composition of rye grass with age.

over the whole growing period and the ratio of cellulose to lignin narrowed gradually to about 4. From what is known of the large decrease in digestibility of grass that follows the formation of the seed, a relatively small change in lignin content must vitally affect availability, unless some other factors are also concerned. This may be the case as is demonstrated by the figures for fructosan content. High in the young samples it falls rapidly with maturity. The peak content appears to occur just about the time of full emergence of the head, but

because the dry weight may still be increasing the maximum on a unit area basis falls later. In this experiment the fructosan per acre attained its maximum at the time of the sixth sample when it amounted to nearly 400 pounds per acre (Fig. 2).

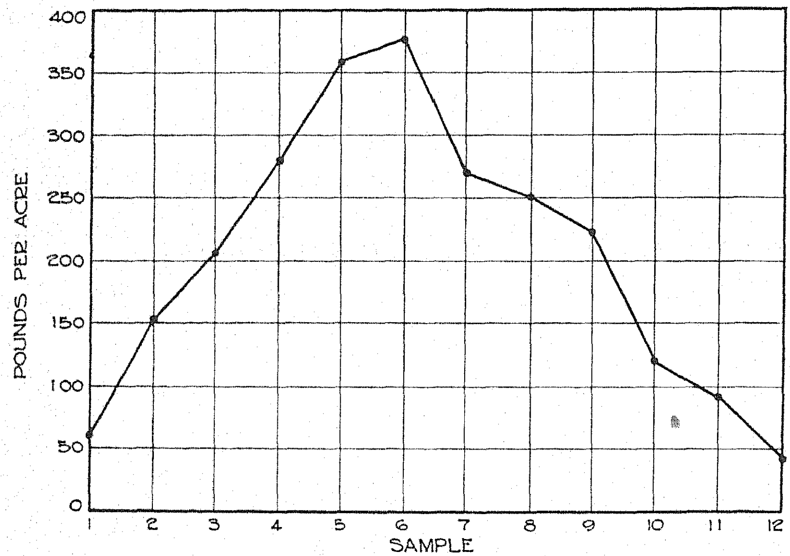

FIG. 2.—Yield of fructosan in rye grass.

Fructosan is extremely soluble and very easily hydrolysed. Its enzymic breakdown has been little studied, but either directly or by bacterial action this carbohydrate is probably of great nutritional importance. Its distribution within the plant has been followed to some extent. Synthesis no doubt occurs in the leaves, but the chief place of storage is the stem and particularly the first internode above ground level which contained as much as 42.8% (Table 3).

TABLE 3.—*Distribution of fructosan in ryegrass, June 2, 1936.*

Plant parts	Fructosan, %	Dry weight, % of aerial parts
Leaves	24.4	25.4
Stem	35.4	51.5
Heads	17.3	23.2
Root	25.0	—
1st internode	42.8	—
2nd internode	34.1	—
Aerial parts	28.1	—

The occurrence of this polysaccharide as a temporary reserve raises a number of physiological questions which cannot be answered at present. There is a strong probability that much of the fructosan is used subsequently for the production of structural constituents par-

ticularly cellulose, because although no increase in dry weight occurred after the time of the sixth or seventh sample, there was thereafter a steady rise in structural constituents and a comparable fall in fructosan (Fig. 3). These analyses demonstrate that there is a

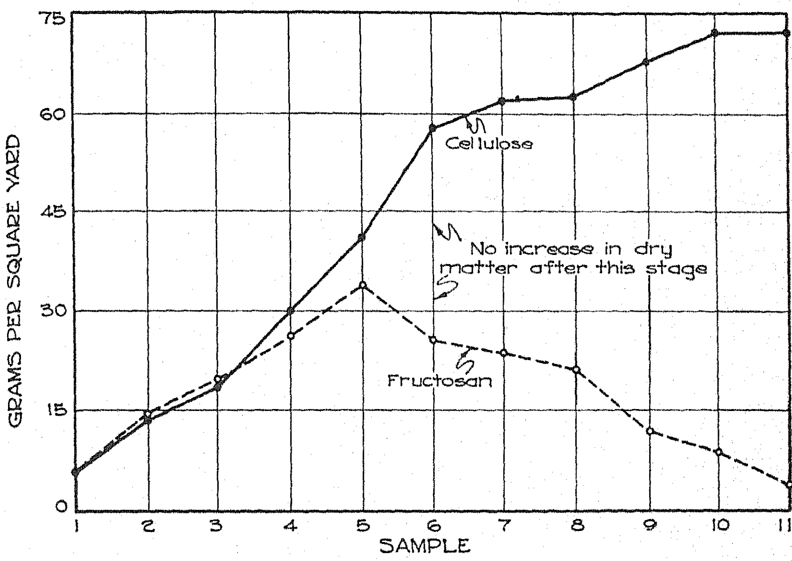

FIG. 3.—Changes in cellulose and frutosan in rye grass expressed on an area basis.

greater difference between young grass and mature grass than a lower lignin content and a higher protein content, and that transformations in the type of carbohydrate present may also be an important factor in affecting availability.

Certain of the plats were recut later in the season in order to obtain information as to the composition of the second growth and, while the experiments were incomplete, there was a strong indication that second growth grass contains a higher percentage of structural constituents and a lower percentage of fructosan than first growth when compared on a basis of equal protein content (Table 4). The data are insufficient to permit of any definite statement, and this question which is of great practical significance calls for further examination.

The cocksfoot analyses (Table 5) are perhaps less interesting than those of rye grass.[5] Cocksfoot evidently contains a considerably higher percentage of structural constituents, even at the young stage. Seven per cent was the lowest lignin content recorded, with an increase up to 12% or more on mature samples. Fructosan was present but in smaller amounts, the maximum being 11% on the first cut taken. The fructosan content declined to maturity but was by no means negligible even in the oldest samples. This is different from its

[5]The full data are to be found in a forthcoming paper in the Biochemical Journal.

TABLE 4.—*Comparison of first and second growth rye grass, 1936, composition expressed as percentage of oven-dry material.*

Sample No.	Date cut	Grams per sq. yd.	Crude protein, %	Cellulose, %	Lignin, %	Fructosan, %
1	May 12	23	11.8	26.1	3.6	25.6
1-1	June 15	51	10.4	38.4	8.2	14.2
2	May 19	54	9.3	26.4	4.7	26.9
2-1	June 29	80	7.5	37.9	10.1	12.2
3	May 26	64	9.1	28.9	5.2	30.1
3-1	July 14	112	7.1	33.2	9.2	8.9
4	June 2	93	7.8	32.0	5.9	28.1
4-1	July 27	109	5.4	42.9	11.5	5.5

behavior in rye grass. Additions of nitrogen were made to a part of the area in order to determine the effect of prolonging vegetative growth. The yield of dry matter was much increased and the nitrogen content enhanced, as would be expected. Little effect was produced in the amounts of cellulose and lignin, though on some samples the cellulose content seemed slightly reduced and the lignin content increased as a result of the applications. The ratio of cellulose to lignin, which might perhaps be considered as some measure of the degree of lignification was curiously enough almost consistently narrower in the plats that had received nitrogen. In all cases, however, the fructosan was reduced, this being in accord with observations on the effect of nitrogen on this constituent in barley (1, 8).

TABLE 5.—*Yield and composition of Cocksfoot, 1937, composition expressed as percentage of oven-dry material.*

Sample No.*	Date cut	Grams per sq. yd.	Crude protein, %	Cellulose, %	Lignin, %	Fructosan, %	Cellulose / Lignin
1-N	May 10	90	12.3	38.5	7.9	11.3	4.9
2-O	May 18	130	11.0	42.4	7.1	11.1	6.0
2-N	May 18	124	15.4	41.3	7.0	9.4	5.9
3-O	May 24	166	9.9	44.4	8.6	8.7	5.2
3-N	May 24	186	12.1	46.0	8.7	5.8	5.3
4-O	May 31	196	7.5	46.8	10.2	8.3	4.6
4-N	May 31	277	12.3	44.7	11.1	4.8	4.0
5-O	June 7	257	7.0	45.8	11.1	7.5	4.1
5-N	June 7	377	10.3	45.8	12.0	5.7	3.8
6-O	June 14	284	5.3	48.9	11.1	6.9	4.4
6-N	June 14	413	10.6	46.2	12.4	5.0	3.7
7-O	June 21	335	5.4	48.6	11.9	7.8	4.1
7-N	June 21	456	9.1	45.6	12.4	7.3	3.7
8-O	June 28	314	5.4	46.4	12.1	9.7	3.8
8-N	June 28	260	7.9	44.3	11.8	8.2	3.8

*Samples with suffix N came from plats receiving nitrogenous fertilizer; those with O from untreated plats. Applications of nitrogen were made as follows: On May 10, ammonium sulfate equivalent to 46 lbs. N per acre; on May 24 and June 7, ammonium sulfate equivalent to 23 lbs. N per acre.

The second growth was taken from all plats after an interval of four weeks, no further additions of nitrogen being made (Table 6). As in the first growth the effect of nitrogen seemed to be manifest in a reduction in fructosan content and an increase in lignin. The fructosan

was in all cases relatively low, but unlike rye grass it cannot be said of the second growth that the percentage content of structural constituents is higher than the first growth when material of approximately equal nitrogen content is compared.

TABLE 6.—*Yield and composition of Cocksfoot (second cut 4 weeks growth) expressed as percentage of oven-dry sample.*

Sample No.*	Date cut	Grams per sq. yd.	Crude protein, %	Cellulose, %	Lignin, %	Fructosan, %
1-O1	June 7	55	12.0	40.1	8.6	6.7
1-N1	June 7	137	19.3	40.8	9.0	3.8
2-O1	June 14	49	13.5	43.5	8.8	3.5
2-N1	June 14	119	17.9	41.0	10.0	2.8
3-O1	June 21	41	12.2	42.1	8.2	6.1
3-N1	June 21	122	14.3	40.8	10.0	5.0
4-O1	June 28	35	11.7	40.5	8.9	6.7
4-N1	June 28	106	14.1	39.8	9.1	6.0
5-O1	July 5	21	12.0	42.7	8.3	5.1
5-N1	July 5	68	14.0	40.8	8.4	5.4
6-O1	July 13	20	12.2	46.8	8.5	5.6
6-N1	July 13	61	13.6	44.1	9.9	5.7
7-O1	July 20	23	10.9	44.8	9.5	3.5
7-N1	July 20	45	12.3	44.4	9.1	4.4
8-O1	July 27	12	10.1	44.2	9.9	2.6
8-N1	July 27	24	13.5	43.8	9.8	3.7

*Samples with suffix N came from plats which originally received nitrogenous fertilizer.

These data have been presented not so much to prove certain theories or to indicate certain changes in grasses, as to demonstrate the possibilities of this approach to studies of composition. In themselves they are insufficient and only a beginning of what will have to be done extensively if a detailed picture is to be obtained of the variation in composition of herbage with age, with fertilizer treatment, and with management. Arising out of the data presented, the following points seem to call for attention and to be capable of solution by an extension of the direct methods of determination just described:

First, what is the nature of the primary and secondary carbohydrate metabolism of grasses? Is fructosan a major temporary reserve only in rye grass, or is it to be found generally in many species? What relationship, if any, is there between fructosan formation and storage and the rapidity of new growth following cutting or grazing? Are there other reserve carbohydrates as yet unidentified?

Second, what is the influence of lignification or lignin deposition on the digestibility of herbage? Are the advantages of feeding young grass so exclusively confined to the higher protein content and greater digestibility of the cellulose as has been supposed, or may not the replacement of much soluble polysaccharide by insoluble structural constituents be also concerned?

Third, what is the nature of the hemicelluloses of grasses? How may they be determined, and what role, if any, do they play in affecting the value of the herbage? Can they act as reserves, as has sometimes been asserted, or should they properly be regarded as structural constituents and consequently out of circulation so far as renewal of

growth after cutting is concerned? Because of limits of time this group has not been discussed, but it should perhaps be stated that in all the samples mentioned the hemicelluloses were probably quantitatively more important than the lignin.

This list of questions could be considerably extended, particularly if the nitrogenous constituents are also included. Most of the questions are quite fundamental to a fuller understanding of grasses and the proper management of grassland. Their solution depends on the further development of biochemical methods in this field and the abandonment of empirical procedures as research tools.

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THE INFLUENCE OF EXCHANGEABLE IONS AND NEUTRAL SALTS ON THE pH OF SOILS[1]

M. PUFFELES[2]

Sörensen and Palitzsch (11),[3] in their investigations on the pH of salt solutions, came to the conclusion that two solutions containing some dissolved inorganic material show the same coloration when tested with an indicator if their pH's are similar. If the concentrations of the two solutions vary, however, the indicator does not show the same color. Thus, they demonstrated the lowering of the pH on the addition of some salt to one of the solutions having similar concentrations and naturally came to the conclusion that the addition of such a salt, whether neutral or not, increases the pH or its activity, which, in its turn, results in a lower reading. Later, they (12) also demonstrated that the determinations of the pH in a neutral salt solution do not agree when measured by means of electrometric and colorimetric systems. Their determinations gave a mean difference of 0.05 to 0.07 between the two methods. They also found that in a 3.5% neutral salt solution the pH is diminished by 0.24.

McBain and Colman (8) found that the rate of inversion caused by 0.25 N/HCl was increased by 8.47% on the addition of 0.25 N/KCl solution. Michaelis and Rona (9) have demonstrated that variations of color in a solution do not depend solely on the pH, but are also affected by the concentration of neutral salt in the solution. They think that changes in the color of the solution are due to the effect of the neutral salt on the dissociation constant of the indicator. They also found that by adding a neutral salt, such as NaCl, to a solution of acetic acid, the dissociation constant of the acid is increased. The influence of a neutral salt on lowering the pH of a given soil is now a well-known fact in the case of humid soils. Such lowering also serves as an index of the unsaturation of the zeolite-complex and of the amount of lime which should be added to the soil. In the case of arid soils very few investigators have observed a diminishing pH value following the addition of a neutral salt. Arrhenius (2) has shown that the presence of salts in certain Egyptian soils has prevented the formation of black alkali. He also points out that the addition of a neutral salt to an alkaline clay (considered an absorptive, saturated clay) produces a greater lowering of the pH than its addition to unsaturated soils and attributes this to the fact that the addition of a neutral salt activates the hydrogen ions and suppresses the OH group. As to the degree of activation exercised by the nonmetallic ions on the hydrogen-ion concentration in the soil, Arrhenius found that Cl is more active than NO_3, while nitrate is more active

[1]Contribution from the Central Laboratories, Dept. of Health, Government of Palestine, Jerusalem. Received for publication May 16, 1939.

[2]Chemist. The author wishes to express his thanks to G. W. Baker for his advice and corrections on this paper and to S. Adler for her assistance in the analytical work reported here.

[3]Figures in parenthesis refer to "Literature Cited", p. 766.

than SO_4. As far as the cations are concerned the strongest is Fe,[4] then come Ca, Mg, K, NH_4, and lastly Na arranged in decreasing strength.

The writer (10) has observed in an investigation of many Jericho soils that the addition of a neutral salt decreases the value of the pH.

Aarnio (1), in his study of the influence of absorbed ions on soil reaction, has found that the pH of clay saturated with a monovalent or bivalent cation decreases with an increase in atomic weight, and is lower in the case of the bivalent cation clays as compared with the monovalent type.

Wiegner, et al. (13, 14, 15) and Gallay (4) measured the viscosity and the ultramicroscopic coagulation of the suspension of different clay cations. In doing this they discovered that the position of these cations in the periodic system was interrelated with the water absorptive and coagulation properties of the clay which they saturate. It was found that, as a rule, the increase in the atomic weight of monovalent and bivalent cations fixed by the clay soils brings about a lessening of the water-absorbing power of the clay cation, increasing at the same time its capacity for coagulation.

It seems reasonable to suggest, therefore, that the absorbed cation might have a specific influence on the stability of the complex, as well as on the pH, and that a neutral salt would also influence the different exchangeable cations.

METHODS

Three different types of soil, *viz.*, a heavy, a light, and a calcareous soil, were chosen for the experiment with a view to discover the influence of neutral salts on the pH in the solutions.

Colorimetric measurements were used of water extracts of the soils rendered as colourless as possible. Since filtration affects the reaction of the extract, the latter were prepared by the centrifuging. In cases where the suspension was not clear, it was clarified with barium sulfate, using Kühn's method (7). The actual measurements were taken with the Hellige comparator. Pyrex glass was used for the determinations of colors in order to avoid errors consequent on the solubility of glass. The water used was twice distilled and its pH determined prior to use. The KCl used was an "A.R." reagent.

The experiments were made in three different ways, as follows: (a) By diluting the soil with different quantities of water and shaking for a fixed length of time (3 minutes), according to Gedroiz (5); (b) by preparing the same dilution (1:5) and shaking for different periods of time; and (c) by preparing artificial soils, such as a Ca, a Mg, a K, and a Na soil, diluting them with different concentrations of N/KCl, and measuring the pH in these preparations.

DESCRIPTION OF SOIL SAMPLES

Samples I and II.—These were red sandy soils taken at the colony of Rehoboth in the Southern District of Palestine. The landscape of the red sandy areas can be described as hilly. With the exception of a surface layer (0.50 cm) which is of a darkish color owing to the organic matter it contains, the profile of the sample

[4]The iron salts of strong acids, in general, tend to hydrolyze in solution giving a rather strongly acid reaction.

shows the same structure. Samples were taken at two depths, namely, 0–50 cms and 50–100 cms.

Samples III and IV.—These were dark red loamy soils of the colony of Hederah in the Northern District of Palestine. They belong to the type of soil developed *in situ* on calcareous rocks with a low content of line ($CaCO_3$ less than 0.5%). They were also taken at two depths, namely, 0–50 cms and 50–100 cms.

Sample V.—This was a dark, dull, brown to red lime and clay soil. It was taken in the Jordan Valley west of Allenby Bridge. It consists of a diluvial sediment at the foot of the mountains which has been destroyed in the course of time and overlaid by a layer of alluvial deposit brought down by mechanical processes (wind, rain, etc.). A pit 1 meter deep was excavated and, since the soil was homogenous, one sample was taken from a depth of 0–100 cms.

RESULTS AND DISCUSSION

Since the results of the mechanical and other determinations of samples I and II, on the one hand, and of samples III and IV, on the other hand, were similar, the data recorded in the tables are averages of two samples. Table 1 shows the results of the mechanical analyses made according to the Sudan method worked out by Beam (3). It also records the lime content of the soil.

TABLE 1.—*Mechanical analysis and lime content of the soils.*

Soil No.	Clay (<0.002 mm) %	Silt (0.002–0.02 mm) %	Fine sand (0.02–0.2 mm) %	Coarse sand (0.2–2 mm) %	$CaCO_3$, calculated from CO_2 %
I	5.4	2.4	70.3	21.9	<0.5
II	57.5	15.6	25.4	1.5	<0.5
III	46.8	20.8	20.0	12.4	36.6

Determinations of the pH were made in the case of each of the five soils in water extracts and in normal potassium chloride solutions. Table 2 shows the values of the pH when using the 3-minute extraction method of Gedroiz (5) with six dilutions ranging from 1:1 to 1:160, as conducted by Joseph and Martin (6) in some of their experiments.

TABLE 2.—*The pH values of the soils at different dilutions and for 3 minute extractions.*

Dilution, soil to water	Water extract			N/KCl extract			Difference		
	Soil No. I	Soil No. II	Soil No. III	Soil No. I	Soil No. II	Soil No. III	Soil No. I	Soil No. II	Soil No. III
1:1	6.8	8.0	8.1	6.65	7.3	7.5	0.15	0.7	0.6
1:5	7.15	8.3	8.5	6.75	7.3	7.9	0.4	1.0	0.6
1:10	7.2	8.4	8.5	7.05	7.3	8.1	0.15	1.1	0.4
1:40	7.1	7.85	8.5	7.05	7.3	8.5	0.05	0.55	0.0
1:80	7.3	7.7	8.5	7.10	7.3	8.6	0.2	0.4	0.1
1:160	7.1	7.4	8.6	7.1	7.3	8.6	0.0	0.1	0.0

Table 3 shows the pH values of the soils, using a 1:5 dilution with five periods of extraction ranging from 3 minutes to 8 days.

TABLE 3.—*The pH values of the soils with different extraction periods.*

Extraction period	Water extract			N/KCl extract			Difference		
	Soil No. I	Soil No. II	Soil No. III	Soil No. I	Soil No. II	Soil No. III	Soil No. I	Soil No. II	Soil No. III
3 mins.......	7.15	8.3	8.5	6.75	7.3	7.9	0.4	1.0	0.6
1 hour.......	7.1	8.0	8.3	7.1	7.3	7.9	0.0	0.7	0.4
1 day........	7.1	8.2	8.3	7.1	7.6	7.9	0.0	0.6	0.4
2 days.......	7.1	8.1	8.3	6.9	7.5	7.9	0.2	0.6	0.4
4 days.......	7.3	8.0	8.1	6.9	7.5	7.9	0.4	0.5	0.2
8 days.......	7.1	8.0	8.1	6.9	7.5	8.1	0.2	0.5	0.0

Table 2 shows that the greatest reduction in pH caused by the addition of a neutral salt occurred in heavy soils. In these soils the reduction reached 1.1 in the 1:10 dilution, but decreased with further dilutions. The two light soils in a 1:5 dilution showed a decrease of 0.40 in the pH values, with further diminution on greater dilution. The calcareous soils showed a lowering of 0.6 in pH vlaues in dilutions of 1:1 and 1:5, while the value decreased still more on further dilution.

In Table 3 it will be noted that neutral salts influenced the pH value most in the case of heavy soils the difference being 1.0 after 3 minutes but lessening with increasing time of extraction. In light soils the pH values were equal after 3 minutes and 4 days (0.4). In calcareous soils the difference in pH was 0.6 after 3 minutes, but remained constant from 1 hour to 2 days (0.4), but decreasing with longer periods of time.

In order to ascertain the influence of the exchangeable cations Ca, Mg, K, and Na on the addition of a neutral salt, the light and heavy soils described above were prepared by treating them with 0.05 N/HCl until they completely lost the above-mentioned cations. The soils were then treated separately with N/$CaCl_2$, $MgCl_2$, KCl, and NaCl, shaken for 24 hours, and washed with distilled water until they became completely free of chlorine. Next, each sample was dried until free of moisture. In order to determine the pH in these specially prepared samples and the influence of neutral salts on them, they were tested with water and N/KCl. Further, the changes undergone by the pH were ascertained by adding different quantities of N/KCl. The results are given in Table 4.

From the results obtained it may be concluded that (a) heavy soils with exchangeable bases always show a higher pH than light soils; and that (b) in a water extract of 1:5 the pH values of different soils with monovalent or bivalent cations decreased with an increase in the atomic weight of the cations and are lower in the case of bivalent cations than in the case of the monovalent cations; (c) that on the addition of different quantities of N/KCl the pH value diminishes in all soils with an increase in KCl, and in heavy soils the diminution is greater than in light soils; and (d) that so far as the influence of

TABLE 4.—*The hydrogen-ion concentrations in water extract (1:5) of artificially prepared soils, quantities of N/KCl and the differences between them.*

$N/KCl:H_2O$	Ca soil				Mg soil			
	Light	Diff.	Heavy	Diff.	Light	Diff.	Heavy	Diff.
0:25	7.2	0.0	7.4	0.0	7.1	0.0	7.3	0.0
1:24	7.2	0.0	7.4	0.0	7.1	0.0	7.3	0.0
5:20	7.2	0.0	7.4	0.0	7.1	0.0	7.3	0.0
10:15	7.2	0.0	7.4	0.0	7.1	0.0	7.2	0.1
15:10	7.15	0.05	7.3	0.1	7.0	0.1	7.0	0.3
20:5	7.1	0.1	7.2	0.2	6.9	0.2	6.8	0.5
25:0	7.0	0.2	6.9	0.5	6.8	0.3	6.6	0.7
$N/KCl:H_2O$	K soil				Na soil			
	Light	Diff.	Heavy	Diff.	Light	Diff.	Heavy	Diff.
0:25	6.8	0.0	7.0	0.0	7.3	0.0	7.5	0.0
1:24	6.8	0.0	6.8	0.2	7.3	0.0	7.3	0.2
5:20	6.6	0.2	6.6	0.4	7.0	0.3	7.0	0.5
10:15	6.5	0.3	6.4	0.6	6.6	0.7	6.7	0.8
15:10	6.5	0.3	6.3	0.7	6.5	0.8	6.4	1.1
20:5	6.4	0.4	6.1	0.9	6.2	1.1	6.0	1.5
25:0	6.2	0.6	5.8	1.2	6.1	1.2	5.6	1.9

KCl on the reaction and its specific influence on the stability of the complex are concerned, Ca soils are most stable, with Mg and K soils next in order, and Na soils last.

SUMMARY

The following conclusions may be drawn from the experiments reported here:

1. The observation that the pH value of a soil is lowered on the addition of a neutral salt is valid not only in the case of humid soils but also in arid soils. We cannot speak here of saturated and unsaturated soils, only more or less saturated soils. All the processes which render humid soils unsaturated also take place in arid climates, but much less intensively.

2. Analytical data confirm the fact that the dilution of 1:5 and an extraction time of 3 minutes give optimum results.

3. On the addition of a neutral salt, the pH value diminishes most in heavy soils and least in light soils.

4. A close relation exists between the position and valency of the absorbed complex and the pH of the soil.

5. In preparing different types of soils, such as Ca, Mg, K, and Na soils, it was observed that bivalent soils, i.e., Ca and Mg soils, were less affected by the addition of neutral salts than the monovalent types, i.e., K and Na soils. Also, Ca soil was less affected than Mg soil and K soil than Na soil.

6. The fact that the addition of a mineral fertilizer to the soil causes a diminution of the pH in the soil is of immense importance to the practical agriculturist. By examining the exchange of bases in the

soil, he can arrive at an accurate estimate of the extent to which the soil would be affected by the addition of a mineral fertilizer and what means should be taken, e.g., addition of lime, in order to prevent the accumulation of acids in the soil.

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THE GROWTH OF KENTUCKY BLUEGRASS AND OF CANADA BLUEGRASS IN LATE SPRING AND IN AUTUMN AS AFFECTED BY THE LENGTH OF DAY[1]

MORGAN W. EVANS AND JAMES M. WATKINS[2]

THIS report is devoted chiefly to a study of the effects of length of day upon the seasonal habits of growth of Kentucky bluegrass (*Poa pretensis* L.) and of Canada bluegrass (*Poa compressa* L.). No critical studies were made of the effects of variations in temperature aside from the effects of those differences occurring naturally at the two seasons when experiments were conducted. It is recognized, however, that the habits of growth of these species of grass may be affected by temperatures (4).[3]

Plants of both Kentucky bluegrass and of Canada bluegrass, grown under the natural photoperiods of late spring and early summer in the latitude of Wooster, Ohio, produce upright shoots. Similar plants grown under the natural photoperiods prevailing during fall and early spring, on the other hand, produce decumbent or semi-decumbent shoots. In rhizome production the two species differ from each other at both of these periods.

Plants of Kentucky bluegrass grown at these two periods are illustrated in Fig. 1. The plant which made its growth in spring and early summer produced relatively few shoots, both shoots and leaves growing in a more or less upright position. Two underground stems or rhizomes were produced. The plant which made its growth in the fall produced a larger number of shoots, but both stems and leaves grew in decumbent or semi-decumbent positions and no rhizomes developed.

At the latitude of Wooster, Ohio, during the time when the experiment was conducted in late spring and early summer, the length of day, from sunrise to sunset, gradually increased from 14.5 hours on May 17 to 15.1 hours on June 10, remained at approximately this length until July 2, then decreased to 15.0 hours. In the experiment conducted in the fall the length of day gradually decreased from 12.3 hours on September 20 to 10.1 hours on November 9. In the spring the average length of day was 15.0 hours; in the fall it was 11.2 hours (3, pages 6–7). From May 17 to July 6 the mean daily temperature was 67° F, and from September 20 to November 9, 52° F. No records were obtained of the night temperatures within the boxes used to cover the short-day plants. Presumably these temperatures were

[1]Paper delivered by the senior author on May 6, 1938, before the Botanical Section of the Ohio Academy of Science. The investigation was conducted at Wooster, Ohio, by the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, cooperating with the Department of Agronomy, Ohio Agricultural Experiment Station, Wooster, Ohio. Received for publication June 8, 1939.

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[3]Figures in parenthesis refer to "Literature Cited", p. 773.

modified to some extent during the 15.5 hours that the plants were covered.

EXPERIMENTAL METHODS

On May 17, 1937, typical plants of Kentucky bluegrass and of Canada bluegrass, grown from commercial seed sown August 24–25, 1936, were transplanted to three separate sets of duplicate plats. In these plats, each of which was approximately 4 x 4 feet, the rows were 1 foot apart and the plants 6 inches apart in the rows. Final records were obtained from 21 plants in each plat, or from 42 for each treatment.

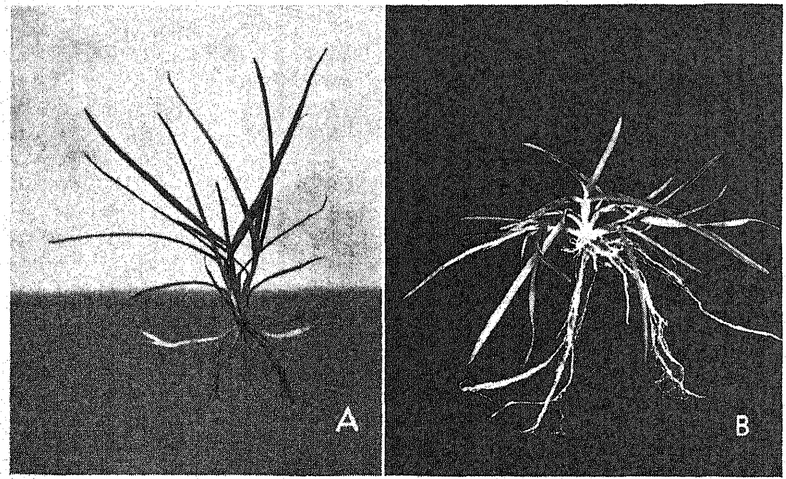

FIG. 1.—Typical young plants of Kentucky bluegrass grown under natural illumination. A, collected July 9, 1937; B, collected November 24, 1937.

One set of duplicate plats grew with normal daily illumination. The second set of plats was artificially illuminated for a sufficient length of time after sunset so that they received light approximately 18 hours each day. For this purpose 12 mazda 200-watt electric light bulbs, automatically controlled by an electric time clock, were used. They were arranged in two rows of six lights each, 4 feet above the ground and spaced 4 feet from center to center. At the surface of the soil the illumination ranged from approximately 65 to 80 foot-candles throughout the area occupied by these plats.[4] Each plat in the third set was covered part of each day with a box measuring approximately 4 x 4 x 4 feet and painted black inside and white outside. There were in each box two 4-inch curved ventilating pipes placed at different levels at the rear, painted black inside so that they admitted no light. The boxes were kept over the plants from 4:30 p.m. until 8:00 a.m. These plants, therefore, received 8.5 hours illumination daily.[5]

[4]Acknowledgments for measurements of the intensity of illumination at night under the electric lights are due to J. P. Ditchman, Nela Park Engineering Department, General Electric Company, Cleveland, Ohio.

[5]Helpful suggestions and advice in regard to the method and equipment used for growing the plants under the different lengths of day were received from H. A. Allard, Division of Tobacco and Plant Nutrition Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture.

Since, with the equipment at hand, there was no way in which the artificial light used at night on the long-day plats could be effectively screened off from the adjacent areas, it was necessary to place the check plats of plants grown under natural illumination at some distance. The two sets of plats were 325 feet apart. The short-day plats were in an area adjoining the check plats. Both groups of plats were located on similar slopes. Between them was an 8% slope which helped to prevent the electric light rays from reaching the check plats. Where the long-day plats were located the slope was about 4%. In the other location it was about 3%. In each location the soil was the Wooster silt loam, with the A horizon about 12 to 14 inches deep.[6] Soil conditions, therefore, were closely similar in all plats.

The lights and the dark boxes were used from May 17 to July 6. The data for this experiment were recorded on July 9.

A second similar experiment was conducted in these plats in the fall of 1937. The seed was sown on August 19 in rows 8 inches apart. The plants were thinned about September 20 to a distance of approximately 4 inches apart. The lights and the dark boxes were used from September 20 to November 26. Final records of the numbers of shoots and rhizomes were obtained from 28 plants under each treatment—with the exception that records were obtained from only 14 plants of Kentucky bluegrass grown under long days. The average degree of elevation of the shoots were based on measurements of from 45 to 60 shoots for each treatment—with the exception of Kentucky bluegrass grown under long days, for which the average degree of elevation is based on measurements of 27 shoots.

Standard errors were computed for the data on shoots and rhizomes for both experiments. The following comparisons were made for each species: Long with natural day, long with short day, and natural with short day. The level of significance was determined from Livermore's (2) "t" table.

HABITS OF GROWTH OF ABOVE-GROUND PARTS OF PLANTS AS AFFECTED BY LENGTH OF DAY

EXPERIMENT CONDUCTED IN LATE SPRING AND EARLY SUMMER

Records in Table 1 show the habits of growth of plants of Kentucky bluegrass grown during spring and early summer, under natural lengths of day, under days 18.0 hours long, and under days 8.5 hours long. Under long days the shoots grew in an upright position, like those produced under natural lengths of day. The number of shoots per plant under long days was about two-thirds as great as on plants grown under natural lengths of day, but only about one-third as great as on the plants grown under short days. The plants grown under short days, compared with those grown under natural conditions, had about twice as many shoots per plant, and they grew in more nearly decumbent positions. Under all lengths of day the percentage of shoots producing inflorescences was small. This may be related, at least to some extent, to the small size in early spring of the plants which had developed from seed sown in the preceding August.

Fig. 2 illustrates the upright habit of the plants of Kentucky bluegrass grown under 18.0 hours illumination, and the procumbent positions of the shoots when the plants were grown under 8.5 hours daily

[6]Acknowledgments are due Mrs. Elizabeth B. Mickelson of the Department of Agronomy, Ohio Agricultural Experiment Station, for the description of the topography and of the soil where this experiment was conducted.

illumination. Table 1 shows that on the plants of this species under long days the number of shoots was reduced and under short days the number of shoots was much greater than on plants grown under natural lengths of day. Significant differences were obtained from all comparisons on the number of shoots per plant under the three lengths of day. The only significant difference obtained on the length of shoots was between the long- and short-day plants.

TABLE 1.—*Records of plants of Kentucky bluegrass and of Canada bluegrass grown in the spring of 1937 under natural, long, and short days.*

Length of day	Shoots			Rhizomes		Ratio of number shoots to rhizomes
	Average per plant		Average length of longest*, mm	Average number per plant	Average length of longest, mm	
	Total number	With inflorescences, %				
Kentucky Bluegrass						
Natural day	31	2	317	52	130	100:167
Long day	20	5	353	38	110	100:190
Short day	61	2	285	41	128	100:67
Canada Bluegrass						
Natural day	55	40	440	27	84	100:49
Long day	35	65	472	8	45	100:23
Short day	80	8	186	18	65	100:22

*Records of lengths were made only of those shoots with inflorescences.

The effects of the lengths of day upon the plants of Canada bluegrass were much the same as upon the plants of Kentucky bluegrass. Under short days the number and percentage of Canada bluegrass shoots with inflorescences were less than on plants grown under long or under natural lengths of day. On the plants grown under both natural and long days, the inflorescences were normal; under short days spikelets with proliferations occurred on 78% of them. The differences in the total number of shoots between any two lengths of day were found to be highly significant. In comparisons of length and

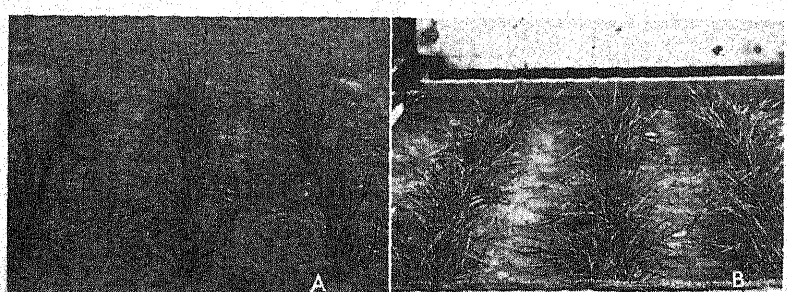

FIG. 2.—Kentucky bluegrass, June 30, 1937. A, plants grown with 18 hours daily illumination; B, plants grown with 8.5 hours daily illumination.

number of shoots with inflorescences, the short-day plants were found to be significantly different from the natural- and long-day plants.

EXPERIMENT CONDUCTED IN THE FALL

On the plants of both species grown in the fall under days approximately 18 hours long, the stems resembled those grown under natural lengths of day in late spring in having both shoots and leaves which tend to grow in an upright position. The number and length of shoots per plant on long-day plants were found to be significantly different from short- and natural-day plants. Table 2 shows that the average elevation of the stems on plants grown under long days was 69 degrees above the horizontal for Kentucky bluegrass and 47 degrees above the horizontal for Canada bluegrass. Under short days, this elevation was 23 and 20 degrees, respectively. Under the natural lengths of day occurring in late November, the shoots were appressed toward the soil almost as much as on the plants grown under 8.5 hours daily illumination.

TABLE 2.—*Growth of Kentucky bluegrass and of Canada bluegrass as affected by different lengths of day.**

Length of day	Shoots			Average number of rhizomes per plant
	Average per plant		Degrees elevation above the surface of the soil	
	Total number	Length of longest†, mm		
		Kentucky Bluegrass		
Natural day	8.9	15	28	0.3
Long day	4.1	86	69	0.7
Short day	10.9	14	23	0.2
		Canada Bluegrass		
Natural day	10.7	18	22	0.9
Long day	7.5	75	47	0.5
Short day	10.9	17	20	1.5

*The records were obtained November 26, 1937, from plants grown from seed sown August 19, 1937.

†The length of each shoot was measured from its base to the juncture of the sheath and blade of the uppermost leaf. None of the shoots on these plants grown in the fall had produced inflorescences.

Under days 8.5 hours long, the habits of growth of the plants of both species closely resembled those of the plants grown under natural lengths of day at this season of the year. The shoots were short and more or less decumbent and had the form of growth commonly described as rosette. Hurd-Karrer (1) induced this habit of growth in winter wheat by reducing the length of day to 8 hours both on plants grown under temperatures ranging from 10° to 12° C and also under temperatures ranging from 20° to 23° C.

DEVELOPMENT OF RHIZOMES AT DIFFERENT SEASONS AS AFFECTED BY LENGTH OF DAY

In the length-of-day experiment extending from May 17 to July 6, as shown in Table 1, there was little difference in the number of

rhizomes[7] per plant of Kentucky bluegrass under 18.0 hours and under 8.5 hours daily illumination. The normal day plants were significantly different in this respect from both the short day and the long day plants. The ratio of rhizomes to shoots, however, was nearly three times as great on the plants grown under long days as on those grown under short days. The number of rhizomes on Canada bluegrass plants was greatest when grown under natural days; however, plants from each length of day were found to be significantly different from each other in number of rhizomes produced. On the Canada bluegrass plants the ratio of rhizomes to shoots was practically the same under long and under short days, but the plants grown under an 18-hour day had only 8 rhizomes per plant while those grown under 8.5 hours daily illumination had 18 rhizomes per plant.

In the plats seeded on August 19, the Kentucky bluegrass produced, as shown in Table 2, 0.7 rhizomes per plant under days 18.0 hours long. This number was reduced to 0.2 under days 8.5 hours long. Canada bluegrass produced, under the longer day, an average of 0.5 rhizome per plant while under the shorter day this number was increased to 1.5.

In respect to the lengths to which the rhizomes grew under short and under long days in neither experiment and for neither species do the records show any very definite trends.

In another set of plats sown August 24–25, 1936, records of the number of rhizomes were obtained from either 5 or 10 plants, with the exception that only 3 plants of Canada bluegrass were examined on April 15, on different dates in the spring of 1937. On the plants of Kentucky bluegrass the following average numbers of rhizomes per plant had developed on these dates; March 22–23, 0.0; April 5, 0.4; April 15, 0.2; April 30-May 1, 0.0; May 15, 6.4. On the plants of Canada bluegrass, the average numbers of rhizomes per plant were as follows: March 22–23, 0.4; April 5, 3.4; April 15, 8.6; May 15, 11.8. These data show that the plants of Kentucky bluegrass produced very few rhizomes up to May 1, after which time there was a rapid increase in their numbers. On the plants of Canada bluegrass, on the other hand, beginning with 0.4 rhizome per plant on March 22–23, there was a gradual increase in their numbers, and by May 15 there were approximately 12 per plant.

On typical plants from other plats of both species sown on April 24, 1937, there was by July 9 an average of 3.2 rhizomes per plant on Kentucky bluegrass plants and an average of only 0.7 rhizomes per plant on Canada bluegrass plants.

In the various experiments at Wooster, Ohio, which have been described, young plants of Kentucky bluegrass produced few rhizomes during late fall or very early spring. They did not begin development in large numbers until May. Young plants of Canada bluegrass, on the other hand, produced relatively large numbers of rhizomes both in late autumn and in very early spring; relatively few began their

[7]In this paper, a rhizome refers to an underground stem having one or more elongated internodes. The rhizome may be either a primary one or a branch, and it may or may not be terminated by an above-ground shoot, though in these experiments few or none of the rhizomes had produced shoots.

growth in late spring and early summer. The data from plants grown under days of different lengths indicate that the difference in the seasonal growth of the rhizomes of these two species is largely due to the tendency for Kentucky bluegrass rhizomes to develop in greatest numbers under relatively long days, and for the rhizomes of Canada bluegrass to grow in largest numbers under short days.

SUMMARY AND CONCLUSIONS

Plants of Kentucky bluegrass and of Canada bluegrass were grown from May 17 to July 6, 1937, under natural lengths of day and under days with 18.0 hours and with 8.5 hours daily illumination. During this period the mean daily temperature was 67° F, and the average length of natural photoperiod was 15.0 hours. A similar experiment was conducted from September 20 to November 26, 1937, with a mean daily temperature of 52° F and an average length of day of 11.2 hours.

Under the relatively long days of late spring and early summer, on the plants of both species the shoots were nearly upright, the internodes became elongated, and on some of the shoots inflorescences developed. On the plants grown under the relatively short days during the fall, the shoots grew in decumbent or semi-decumbent positions, the stems were not elongated, and no inflorescences developed. Likewise, on the plants illuminated for 18.0 hours daily, both in late spring and early summer and also in the fall, irrespective of the differences in temperatures at these seasons, the shoots grew in upright or nearly upright positions and to relatively great lengths. In the spring, particularly on plants of Canada bluegrass, a large proportion of the shoots produced inflorescences. On the plants illuminated 8.5 hours daily, the shoots grew in decumbent or semi-decumbent positions, the internodes of the stems were not elongated, and few or no inflorescences developed.

The rhizomes of Kentucky bluegrass developed in greater numbers during late spring and early summer than in late fall and early spring. Under experimental conditions in late spring the ratio of rhizomes to shoots was about three times as great, and in the fall the number of rhizomes per plant was much greater under long days than under short days. The rhizomes of Canada bluegrass developed in greatest numbers in late fall and early spring. Under experimental conditions at both times, greater numbers of rhizomes developed under short days than under long days.

The distinguishing habits of growth of plants of Kentucky bluegrass and of Canada bluegrass during late spring and early summer are due primarily to the relatively long days occurring then. Likewise, the habits of growth peculiar to the fall season are due primarily to the short days occurring at that time.

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A SIMPLE MEASURE OF KERNEL HARDNESS IN WHEAT[1]

J. W. Taylor, B. B. Bayles, and Colburn C. Fifield[2]

ANY simple test that will aid the wheat breeder in measuring characteristics of grain is of value in increasing the efficiency of the breeding program. In the eastern soft wheat region hard wheats are being used extensively as parents to secure resistance to various diseases and a simple test is especially needed for identifying, in the early generations, hybrid lines with soft grain. Hard wheats in general produce coarse granular flour and soft wheats fine smooth flour. The particle size index test developed by Cutler and Brinson[3] appears to differentiate varieties in a very satisfactory way so far as this character is concerned. It is slow, however. The doughball time test has also been suggested by Cutler and Worzella[4] as a measure of quality for small samples. Since the degree of granulation of a flour seems to be related to hardness of the grain, it occurred to the authors that a pearler such as is used in the inspection of barley and which has also been used for studies in the milling of parboiled rice, might be useful in estimating the hardness of wheat samples. Some preliminary trials seemed to verify this assumption and hence a more extensive investigation was planned and carried out. The results appear promising enough to justify presenting the results.

MATERIALS AND METHODS

The pearler consists of an enclosed grinding stone attached to a ⅛ h. p. direct-drive electric motor. An interval timer, a balance sensitive to 0.01 gram, and a set of Tyler screens completes the apparatus necessary for the pearling test.

Preliminary tests were made on grain of varieties grown in field plats at the Arlington Experiment Farm, Arlington, Va. Later samples from the varieties in the uniform soft winter wheat nurseries grown at several stations in the eastern states were studied. Also, in order to obtain data with a wider range of kernel types, samples of a few winter and spring varieties grown in field plats at experiment stations in the western United States were included.

The wheat was stored for two months or more prior to pearling in an ordinary seed storage room. The moisture in the grain varied between 10 and 11% and no shriveled or badly broken grain was used. The procedure used in the test was as follows:

1. Approximately 100 grams of wheat were placed on a No. 6 Tyler screen held over a No. 8. After shaking a definite number of times by hand, three 20-gram samples were weighed from the grain remaining on the No. 8 screen.

2. A sample was placed in the pearler and the latter started and run exactly 3 minutes.

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[1]Contribution from the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture. Received for publication June 15, 1939.

[2]Agronomists and Associate Baking Technologist, respectively.

[3]Cutler, G. H., and Brinson, G. A. The granulation of whole wheat meal and a method of expressing it numerically. Cereal Chem., 12:120–129. 1935.

[4]Cutler, G. H., and Worzella, W. W. A modification of the Saunders' test for measuring "quality" of wheats for different purposes. Jour. Amer. Soc. Agron., 23:1000–1009. 1931.

3. The grain and rubbed-off material were removed from the machine, screened on a No. 20 screen, and the grains riding the screen weighed to the hundredth gram. From this weight the percentage pearled off was calculated.

EXPERIMENTAL RESULTS

Table 1 gives the percentage pearled off of seven varieties of wheat grown at Arlington Farm in each of five years. The averages show little difference between Kawvale and Purkof. Red Rock could be separated from them each year by the difference in pearling results. Forward, though classed as soft red winter, is decidedly harder by this test than Leap, Trumbull, or Nittany. The last three varieties are considered among the softest of the red winter varieties and probably rank in softness in the order shown.

TABLE 1.—*Percentage of kernels pearled off of seven varieties of soft red winter wheat grown in each of five years at the Arlington Experiment Farm, Arlington, Va.*

Variety	Year and percentage of grain pearled off					
	1934	1935	1936	1937	1938	Average
Purkof	25.5	25.1	23.9	22.0	20.8	23.5
Kawvale	23.8	23.6	22.4	27.9	22.0	23.9
Red Rock	32.1	27.5	27.7	28.0	24.6	28.0
Forward	33.4	30.9	30.3	33.4	26.4	30.9
Trumbull	37.5	35.3	33.2	33.2	30.9	34.0
Nittany	39.9	35.1	35.8	34.8	31.9	35.5
Leap	39.3	35.1	37.9	37.8	32.5	36.5

The results of a more extensive study involving 27 varieties grown in the uniform soft winter wheat nurseries in 1936 at five stations, *viz.*, Lincoln, Neb.; Urbana, Ill.; Ithaca, N. Y.; Kearneysville, W. Va.; and Arlington, Va., are presented in Table 2. Each pearling value given is an average of three determinations. Index of particle size from the same lots of grain grown at Ithaca and Kearneysville and doughball time for those grown at Urbana and Kearneysville are also given for comparison. Index of particle size is based on single determinations only and doughball time is an average of four determinations. Generalized standard errors for the pearling test are also given in Table 2. The figures given are the standard errors of the mean applicable to the determination for each individual variety. Inspection of the data indicated no relation between standard errors and percentage pearled off and consequently generalized standard errors are believed to be reliable for the purposes for which they are used. In this table varieties are arranged in the order of softness of grain as indicated by the pearling test.

The relative ranking of the varieties for particle size index and doughball time is in close agreement with the results obtained by Worzella and Cutler[5] for the same varieties grown at Lafayette, Ind.

[5]WORZELLA, W. W., and CUTLER, G. H. Character analysis of winter wheat varieties. Jour. Amer. Soc. Agron., 30:430–433. 1938.

TABLE 2.—*Percentage of grain pearled off from 27 varieties of wheat grown at five stations in 1936, and the particle size index and dough-ball time at two stations.*

Variety*	C. I. No.	Station and percentage pearled off						Station and particle size index		Station and dough-ball time†	
		Lincoln	Urbana	Ithaca	Kearneys-ville	Arlington	Av.	Ithaca	Kearneys-ville	Urbana	Kearneys-ville
Nittany	6962	38.7	35.3	35.9	38.3	35.8	36.8	35.2	33.0	72	43
Goldcoin	6971	35.1	34.7	41.7	37.0	34.7	36.6	37.0	33.6	26	25
Dawson	6943	36.8	34.3	38.0	40.8	32.2	36.4	35.2	34.8	31	26
Fulhio	6999	37.3	35.7	38.8	35.1	35.0	36.4	39.0	35.4	50	43
Honor	6161	36.5	34.1	38.2	38.3	33.2	36.1	37.6	35.0	30	26
Valprize	11539	37.2	37.1	32.3	37.9	34.1	35.7	35.2	35.4	48	42
Trumbull	5657	37.8	34.1	36.9	34.3	33.2	35.3	33.8	34.0	53	43
Rudy	5656	36.6	33.4	33.1	35.9	33.3	34.5	32.4	29.8	68	40
Currell	3326	37.3	33.5	33.1	32.9	33.4	34.0	39.6	30.8	56	45
Gladden	5644	35.3	33.7	30.9	33.8	31.9	33.1	36.4	35.0	43	33
Illinois No. 2	11537	33.8	33.4	30.2	31.2	31.6	32.0	31.0	31.4	122	104
Nabob	8869	30.8	33.7	29.9	32.3	30.6	31.5	27.4	29.6	61	42
Purdue No. 1	11380	30.6	32.6	31.0	31.7	31.0	31.4	31.2	34.4	60	48
Fulcaster	6471	34.1	31.0	27.6	33.0	28.0	31.2	27.8	28.4	58	41
Forward	6691	33.3	29.5	29.4	29.8	30.3	30.5	29.6	28.0	67	45
Mediterranean selection	11567	30.5	29.9	32.4	31.3	27.3	30.3	33.4	31.2	47	35
Harvest Queen	6199	30.9	30.9	28.6	31.5	29.4	30.3	31.2	30.6	56	49
Baldrock	11538	30.7	30.3	26.9	31.0	30.8	29.9	25.2	25.6	68	47
Red Rock	6951	34.5	30.4	28.3	28.8	27.7	29.9	32.2	26.2	100	51
Poole	3488	30.8	29.1	28.0	29.4	29.3	29.3	31.4	29.2	61	44
Wisconsin Pedigree 2	6683	29.6	30.0	27.7	28.6	28.3	28.8	28.0	27.4	103	73
Michigan Amber	5620	28.5	29.0	27.5	28.3	27.0	28.1	27.2	27.6	90	71
Minhardi	5149	28.3	27.8	25.5	25.4	26.1	26.6	36.2	26.4	141	66
Minturki	6155	27.6	28.1	23.8	26.6	24.4	26.1	26.8	24.0	163	119
Kawvale	8180	23.8	24.6	20.8	26.2	22.4	23.6	17.0	18.2	154	106
Purkof	8381	23.0	21.0	19.1	22.3	23.9	21.9	20.0	20.8	179	153
Kharkof	1442	22.4	21.7	20.4	23.2	21.2	21.8	19.8	21.0	109	86
Station average		32.3	31.1	30.2	31.7	29.9		31.0	29.5	78.4	57.3
Standard error of varietal means		0.050	0.064	0.107	0.102	0.050					

*All varieties listed are soft red winter varieties with the exception of Goldcoin, Dawson, and Honor, which are white winter varieties, and Wisconsin Pedigree 2, Minturki, and Kharkof, which are hard red winter varieties.

†Made by Dr. E. G. Bayfield of Wooster, Ohio, and are the averages of four 4-gram doughballs.

The order of the varieties with respect to pearling is in substantial agreement with their supposed or known hardness of grain. Thus all the hard and semihard winter wheats are at the bottom of the table, and recognized soft wheat varieties are at the top, with others generally recognized as intermediate in the middle. It might be expected that since Nittany originated as a selection from Fulcaster it should resemble the latter in grain hardness. Observations other than those presented herein have indicated it to be softer than Fulcaster.

The interstation correlation coefficients for the percentage pearled off for five stations, for particle size index for two stations, and for doughball time for two stations are given in Table 3. The correlations for pearling and particle size at two stations and for pearling and doughball time at two stations are also given. These were calculated from the data of Table 2. The ten interstation correlation coefficients for pearling are, with one exception (Ithaca vs. Lincoln $r=0.863$), above 0.9. This indicates that the relative hardness of the grain of the different varieties as measured by the pearling test was much the same regardless of where it was grown.

TABLE 3.—*Correlation coefficients of percentage pearled off, particle size index, and doughball time for grain of 27 wheat varieties grown at several experiment stations.*

Characters correlated and station where grown	Kearneysville	Urbana	Ithaca	Lincoln
Pearling vs. pearling:				
Arlington	0.922	0.929	0.917	0.929
Kearneysville	—	0.936	0.921	0.906
Urbana	—	—	0.920	0.958
Ithaca	—	—	—	0.863
Particle size vs. particle size:				
Kearneysville	—	—	0.857	—
Doughball time vs. doughball time:				
Kearneysville	—	0.936	—	—
Pearling vs. particle size index	0.857	—	0.835	—
Pearling vs. doughball time	−0.769	−0.755	—	—

Least highly significant value ($P=0.01$) of r for 27 varieties $=0.4869$.

The interstation coefficients for particle size and for doughball time were also high, $r=0.857$ and 0.936. The lower coefficient for particle size is due, in part at least, to what appears to have been an error in making the determination on Minhardi from Ithaca. This figure is not in line with the other data in this study nor with the results of Worzella and Cutler[6] who also found this variety to give a relatively low index.

The coefficients for pearling vs. particle size for Kearneysville and Ithaca are 0.857 and 0.835 and those for pearling vs. doughball time for Kearneysville and Urbana are −0.769 and −0.755. Reference to Table 2 and Fig. 1, which shows the percentage pearled off, the particle size index, and the doughball time for the varieties grown at Kearneysville, indicates that somewhat lower coefficients for pearling

[6]See footnote 5.

vs. doughball time are due largely to a few varieties, such as Illinois No. 2, which has a longer doughball time, and Kharkof, which has a shorter doughball time, than the other characters would indicate.

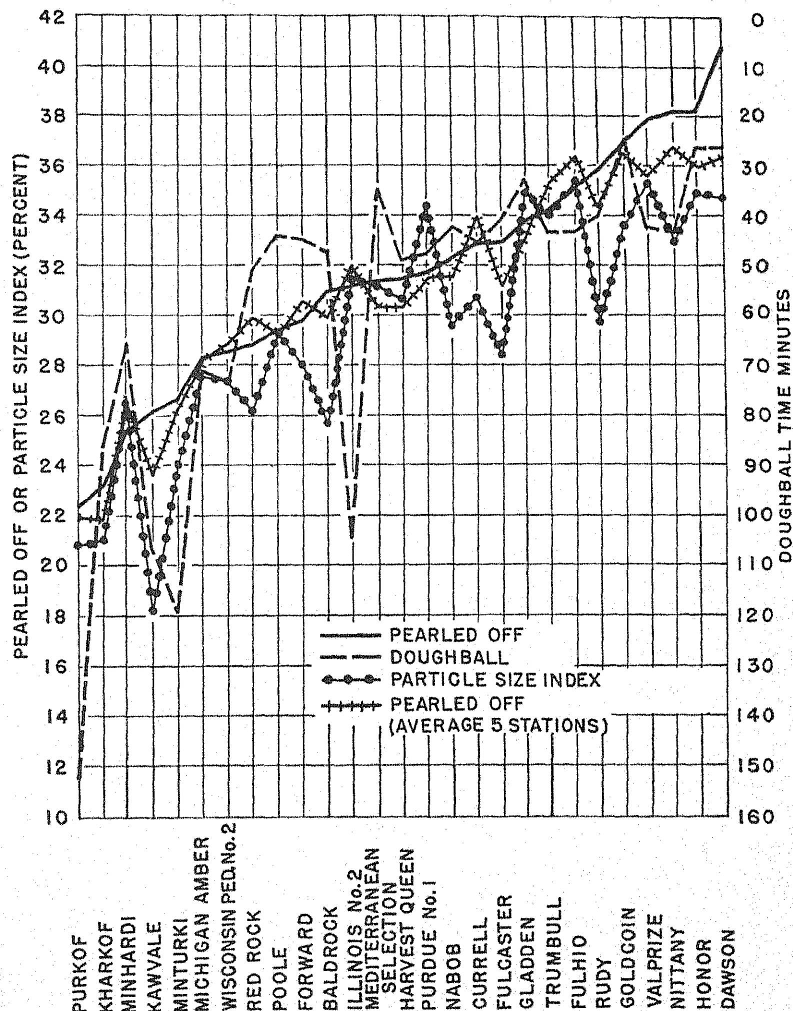

FIG. 1.—Percentage of kernel pearled off, particle size index, and doughball time for 27 varieties of winter wheat grown at Kearneysville, W. Va., and average percentage pearled off for the same varieties grown at four other stations.

No reasons for the lack of agreement for these particular varieties are known, but these and other data seem to justify the conclusion that the differences are varietal and not due to random errors.

TABLE 4.—*Percentage of grain pearled off, particle size index, doughball time, and percentage of protein for samples of spring wheat varieties grown in the western states.*

Item	Marquis	White Federation	Baart	Onas	Federation	Pacific Bluestem	Irwin Dicklow	Lemhi	Av. of 5 varieties	Av. of 8 varieties
1935 Dryland Composite*										
Pearled off, %	22.6	26.4	36.2	36.8	38.6	—	—	—	32.1	—
Particle size index	14.0	15.2	28.6	29.6	29.8	—	—	—	23.4	—
Doughball time, min	264	264	120	182	180	—	—	—	202	—
Protein, %	11.7	11.6	11.7	9.7	10.0	—	—	—	10.9	—
1935 Irrigated Composite†										
Pearled off, %	25.4	25.2	31.7	32.3	36.6	35.5	35.5	35.5	30.2	32.2
Particle size index	13.8	13.6	25.0	23.2	24.0	26.0	24.8	26.0	19.9	22.1
Doughball time, min	233	92	36	40	38	35	30	32	88	67
Protein, %	10.6	10.2	11.3	9.2	9.4	10.8	10.5	9.2	10.1	10.2
1937 Aberdeen, Idaho										
Pearled off, %	24.1	25.3	35.3	35.5	35.1	37.4	38.2	40.1	31.1	33.9
Particle size index	18.6	15.8	26.4	27.6	25.6	31.6	32.2	34.0	22.8	26.5
Doughball time, min	161	76	31	36	41	30	23	26	69	53
Protein, %	10.3	9.8	10.3	8.5	8.9	9.9	8.4	8.2	9.6	9.3

1937 Bozeman, Mont.										
Pearled off, %	27.5	28.1	34.7	36.5	35.8	35.4	35.3	37.4	32.5	33.8
Particle size index	16.4	20.0	25.0	32.2	28.6	30.8	35.8	34.0	24.4	27.9
Doughball time, min	173	88	33	36	31	33	27	30	72	56
Protein, %	12.4	9.5	11.0	8.2	8.2	9.4	7.9	8.2	9.9	9.4
1938 Composite‡										
Pearled off, %	20.1	21.2	27.9	30.5	27.1	—	—	—	25.4	—
Particle size index	13.6	15.6	24.8	28.4	27.8	—	—	—	22.0	—
Doughball time, min	240	178	42	85	59	—	—	—	121	—
Protein, %	11.6	10.6	11.3	9.1	9.3	—	—	—	10.4	—
Average 3 Samples										
Pearled off, %	25.7	26.2	33.9	34.8	35.8	36.1	36.3	37.7	31.3	33.3
Particle size index	16.3	16.5	25.5	27.7	26.1	29.5	30.9	31.3	22.4	25.5
Doughball time, min	189	85.3	33.3	37.3	36.7	32.7	26.7	29.3	76.3	58.8
Protein, %	11.1	9.8	10.9	8.6	8.8	10.0	8.9	8.5	9.8	9.6
Average 5 Samples										
Pearled off, %	23.9	25.2	33.2	34.3	34.6	—	—	—	30.2	—
Particle size index	15.3	16.0	26.0	28.2	27.2	—	—	—	22.5	—
Doughball time, min	214.2	139.6	52.4	75.8	69.8	—	—	—	110.4	—
Protein, %	11.3	10.3	11.1	8.9	9.2	—	—	—	10.2	—

*Composite of grain from Pendleton and Union, Ore.; Pullman, Wash.; and Sandpoint, Idaho.
†Composite of grain from Aberdeen, Idaho; Bozeman, Mont.; and Logan, Utah.
‡Composite of grain from Pendleton, Ore.; Mesa, Ariz.; Pullman and Lind, Wash.; Aberdeen, Idaho; and Bozeman, Mont.

The percentage pearled off, particle size index, and doughball time were determined for several samples of spring and winter wheat grown in the western United States in connection with other studies of quality characteristics of these varieties. The data are given in Table 4 for spring wheat and in Table 5 for winter wheat. The pertinent results are presented graphically in Figs. 2 and 3. Data from dry land and from irrigated stations are included. In some cases the data are for grain from individual stations and in others for composite samples made up of grain from several stations. The protein content of each lot is included for comparison. The varieties, it will be noted, range from typical hard spring and hard winter varieties, such as Marquis and Kharkof, to the very soft common white and club wheats, such as Irwin Dicklow and Albit.

TABLE 5.—*Percentage of grain pearled off, particle size index, doughball time, and percentage of protein for samples of winter wheat varieties grown in the western states.*

Item	Kharkof	Ridit	Triplet	Hybrid 128	Albit	Golden	Rex	Av. of 7 varieties
				1935 Composite*				
Pearled off, %	28.2	30.5	33.8	33.8	33.5	34.0	36.3	32.9
Particle size index	14.6	15.6	24.0	22.2	28.0	26.8	28.4	22.8
Doughball time, min	110	117	102	27	48	37	140	83.0
Protein, %	9.6	9.9	9.1	8.5	8.9	8.4	8.6	9.0
				1937 Composite†				
Pearled off, %	24.3	22.7	29.4	31.7	31.2	30.8	35.0	29.3
Particle size index	15.2	14.2	26.2	23.2	23.6	22.8	29.2	22.1
Doughball time, min	71	73	48	29	35	35	117	58.3
Protein, %	12.1	8.7	11.0	12.0	11.3	11.5	11.7	11.2
				1938 Composite‡				
Pearled off, %	19.0	19.2	25.5	26.4	27.2	27.8	34.7	25.7
Particle size index	13.2	12.8	20.6	19.4	21.6	24.2	27.8	19.9
Doughball time, min	93	83	53	33	35	32	106	62.1
Protein, %	10.1	11.0	9.3	10.1	9.8	9.9	9.1	9.9
				Average 3 Samples				
Pearled off, %	23.8	24.1	29.6	30.6	30.6	30.9	35.3	29.3
Particle size index	14.3	14.2	23.6	21.6	24.4	24.6	28.5	21.6
Doughball time, min	91.3	91.0	67.7	29.7	39.3	34.7	121.0	67.8
Protein, %	10.6	9.9	9.8	10.2	10.0	9.9	9.8	10.0

*Composite of grain from Pendleton and Union, Ore., and Pullman, Wash.
†Composite of grain from Pendleton, Ore., and Pullman, Wash.
‡Composite of grain from Pendleton and Union, Ore.; Pullman, Wash.; and Moscow and Sandpoint, Idaho.

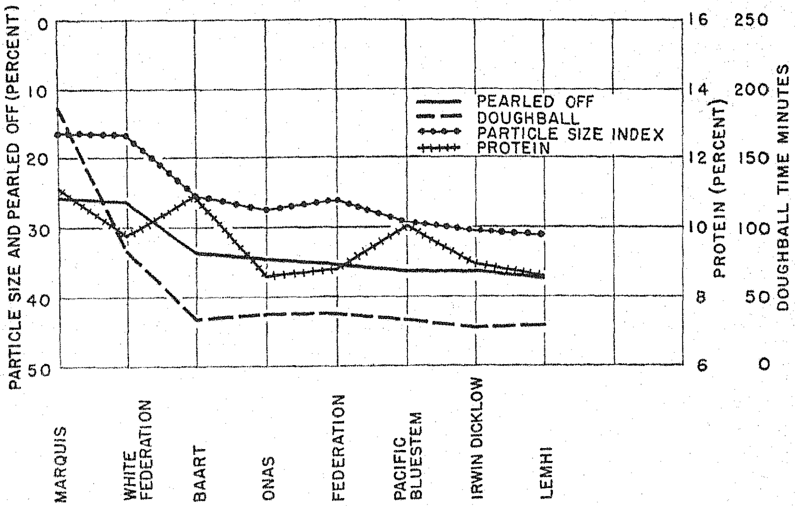

FIG. 2.—Percentage of kernel pearled off, particle size index, doughball time, and percentage of protein in three lots of eight varieties of spring wheat.

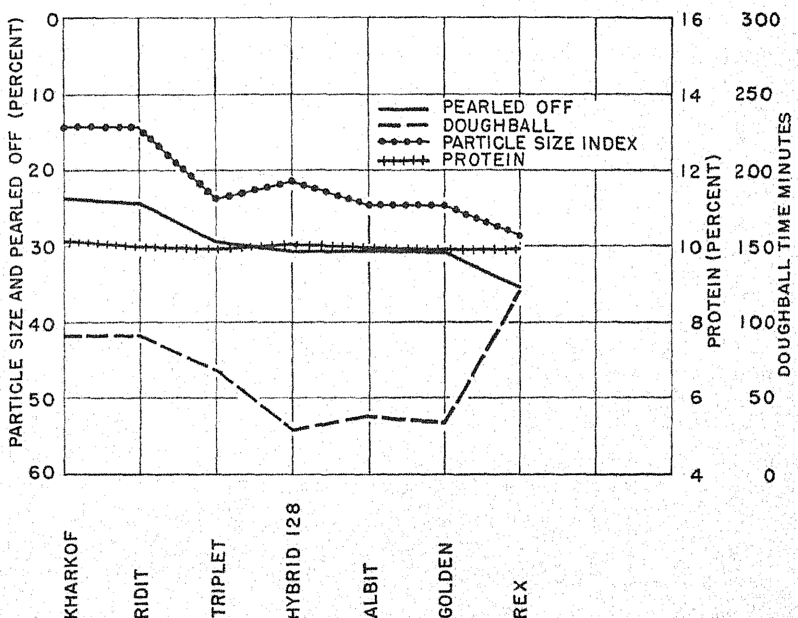

FIG. 3.—Percentage of kernel pearled off, particle size index, doughball time, and percentage of protein in three lots of seven varieties of winter wheat,

The percentage pearled off, particle size index, and doughball time were determined for several samples of spring and winter wheat grown in the western United States in connection with other studies of quality characteristics of these varieties. The data are given in Table 4 for spring wheat and in Table 5 for winter wheat. The pertinent results are presented graphically in Figs. 2 and 3. Data from dry land and from irrigated stations are included. In some cases the data are for grain from individual stations and in others for composite samples made up of grain from several stations. The protein content of each lot is included for comparison. The varieties, it will be noted, range from typical hard spring and hard winter varieties, such as Marquis and Kharkof, to the very soft common white and club wheats, such as Irwin Dicklow and Albit.

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Item	Kharkof	Ridit	Triplet	Hybrid 128	Albit	Golden	Rex	Av. of 7 varieties
				1935 Composite*				
Pearled off, %	28.2	30.5	33.8	33.8	33.5	34.0	36.3	32.9
Particle size index	14.6	15.6	24.0	22.2	28.0	26.8	28.4	22.8
Doughball time, min.	110	117	102	27	48	37	140	83.0
Protein, %	9.6	9.9	9.1	8.5	8.9	8.4	8.6	9.0
				1937 Composite†				
Pearled off, %	24.3	22.7	29.4	31.7	31.2	30.8	35.0	29.3
Particle size index	15.2	14.2	26.2	23.2	23.6	22.8	29.2	22.1
Doughball time, min.	71	73	48	29	35	35	117	58.3
Protein, %	12.1	8.7	11.0	12.0	11.3	11.5	11.7	11.2
				1938 Composite‡				
Pearled off, %	19.0	19.2	25.5	26.4	27.2	27.8	34.7	25.7
Particle size index	13.2	12.8	20.6	19.4	21.6	24.2	27.8	19.9
Doughball time, min.	93	83	53	33	35	32	106	62.1
Protein, %	10.1	11.0	9.3	10.1	9.8	9.9	9.1	9.9
				Average 3 Samples				
Pearled off, %	23.8	24.1	29.6	30.6	30.6	30.9	35.3	29.3
Particle size index	14.3	14.2	23.6	21.6	24.4	24.6	28.5	21.6
Doughball time, min.	91.3	91.0	67.7	29.7	39.3	34.7	121.0	67.8
Protein, %	10.6	9.9	9.8	10.2	10.0	9.9	9.8	10.0

*Composite of grain from Pendleton and Union, Ore., and Pullman, Wash.
†Composite of grain from Pendleton, Ore., and Pullman, Wash.
‡Composite of grain from Pendleton and Union, Ore.; Pullman, Wash.; and Moscow and Sandpoint, Idaho.

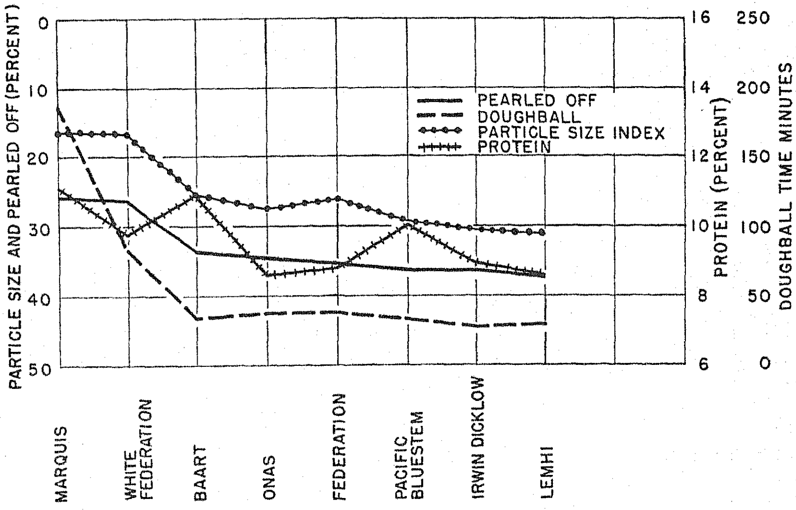

FIG. 2.—Percentage of kernel pearled off, particle size index, doughball time, and percentage of protein in three lots of eight varieties of spring wheat.

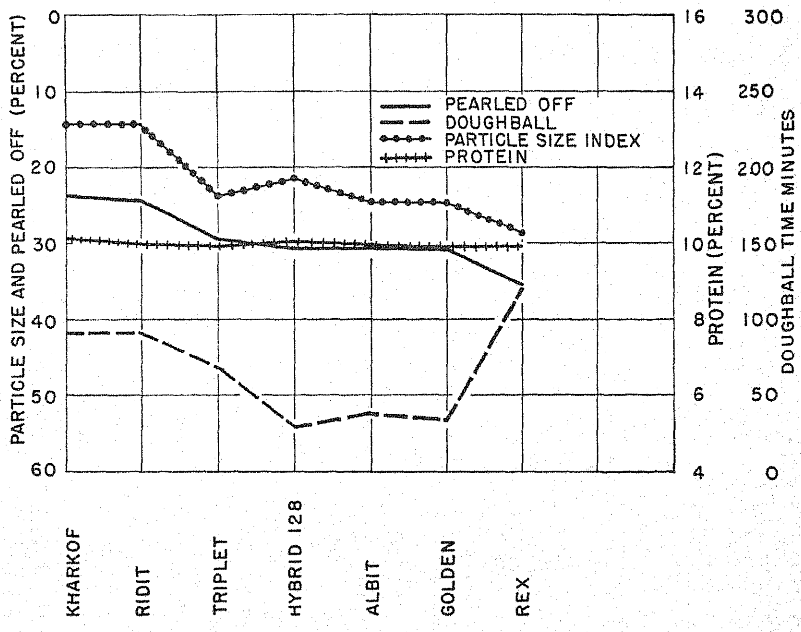

FIG. 3.—Percentage of kernel pearled off, particle size index, doughball time, and percentage of protein in three lots of seven varieties of winter wheat.

The agreement between the percentage pearled off and the particle size index is very good as may be seen by examining the data for individual tests in Tables 4 and 5 or for the averages in Figs. 2 and 3. The large differences in size and shape of the kernels of these varieties might be expected to affect the pearling results and, therefore, disturb the relationship between the percentage pearled off and particle size index, but such apparently was not the case.

The percentage pearled off and the doughball time also show fair agreement for most varieties. A striking exception to this is the winter variety Rex which pearled easiest, yet had the longest doughball time in each of three sets of samples (Fig. 3). The pearling test and index of particle size also show only a slight difference between the spring wheats Marquis and White Federation, while a decided difference was shown in doughball time.

There appears to be only a slight relationship, if any, between the percentage pearled off and the protein content or between the particle size index and the protein content for either the winter or spring varieties.

SUMMARY

A simple pearling test for measuring the hardness of wheat kernels is described. The test is economical with respect to equipment, time, and quantity of grain.

The results are consistent with what is known regarding the relative hardness of different varieties and very high interstation correlations were obtained.

High correlation coefficients were found between the percentage of the kernels pearled off and the particle size index.

Only slightly lower negative correlation coefficients were obtained between the percentage of kernels pearled off and the doughball time. Certain varieties, however, reacted quite differently to the two tests.

Little correlation was found between the percentage pearled off, particle size index, doughball time, and protein content of the grain of the varieties studied.

GROWTH HABIT OF SOME WINTER WHEAT VARIETIES AND ITS RELATION TO WINTERHARDINESS AND EARLINESS[1]

K. S. Quisenberry and B. B. Bayles[2]

WHEAT varieties have been grouped into three general classes, namely, winter, intermediate, and spring, based on their habit of growth. Actually, as has been pointed out by Percival; Clark, Martin, and Ball; and Bayles and Martin,[3] and others, there is a continuous series of varieties or strains from those having very early spring growth habit to those with an extreme degree of winter habit. Thus, within the varieties commonly classed as winter, there are different degrees of winterness. Numerous papers have reported the growth habit of wheat varieties at individual stations for one or more years, but the authors have not seen publications giving data on the growth habit of the same varieties grown under widely different environmental conditions. In order to study this problem, several varieties were seeded in the spring at eight experiment stations and their relative degree of winterness determined. The relation between growth habit, winterhardiness, and time of heading from fall seeding will also be discussed.

Nineteen varieties of wheat classified as having winter habit, one with intermediate habit, and one with spring habit of growth were seeded on three dates in the spring of 1934, 1935, and 1936 at each experiment station. Seven other varieties having winter habit of growth were grown for 1 or 2 years. The name, latitude, and longitude of each station are given in Table 1. The average critical seeding date after which Harvest Queen, Karmont, Minhardi, Denton, Red Rock, and Odessa did not produce heads the same year from at least 5 to 10% of the culms is also given, together with the deviations from this date for each station as compared with Denton, Tex., and also the calculated deviations based on Hopkins' bioclimatic law.[4] These six varieties were chosen because, from the data obtained, it was possible to establish the critical date more accurately. The critical date for seeding the above-mentioned varieties at Denton, Tex., was January 29, whereas at Pullman, Wash., it was March 25, or 55 days later. The critical dates for the other stations were between these two.

According to Hopkins' law, biological phenomena controlled by seasonal changes such as heading dates of wheat should take place in the spring 4 days later for each degree of latitude, 4 days earlier for each 5° of longitude from east to west, and 1 day later for each in-

[1]Contribution from the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture. Received for publication June 26, 1939.
[2]Agronomists.
[3]Percival, J. The wheat plant; a monograph. London: 463 pages, illus. 1921.
Clark, J. A., Martin, J. H., and Ball, C. R. Classification of American wheat varieties. U. S. D. A. Bul. 1074. 1922.
Bayles, B. B., and Martin, J. F. Growth habit and yield in wheat as influenced by time of seeding. Jour. Agr. Res., 42:483–500. 1931.
[4]Hopkins, A. D. Bioclimatics. U. S. D. A. Misc. Pub. 280. 1938.

TABLE 1.—*Critical date of seeding for certain varieties of wheat, the calculated date based on Hopkins' law, and the latitude, longitude, and altitude of the stations where the varieties were grown.*

Station	Latitude	Longitude	Altitude, feet	Critical date of seeding	Deviation from Denton, Tex.	
					Actual date	Hopkins' law
Denton, Tex.	33°10′	97°10′	600	Jan. 29	0	0
Tucson, Ariz.	32°13′	110°56′	2,400	Jan. 28	−1	3
Woodward, Okla.	36°27′	99°33′	2,002	Feb. 7	9	25
Manhattan, Kans.	39°10′	96°33′	1,100	Feb. 17	19	30
Lincoln, Nebr.	40°49′	95°45′	1,180	Feb. 19	21	37
Pendleton, Ore.	45°38′	118°44′	1,100	Mar. 14	44	37
Akron, Colo.	40°	103°	4,560	Mar. 15	45	62
Pullman, Wash.	46°48′	117°6′	2,532	Mar. 25	55	57

crease of 100 feet in altitude. The actual and calculated critical dates agree fairly well at some stations while at other stations they differ considerably. For example, at Akron, Colo., the observed critical date was 45 days later than at Denton, Tex., while according to Hopkins' law it should be 62 days later. An examination of temperature records showed that the months of February, March, and April averaged 0.4° above normal at Denton and 1° above normal at Akron, for the years during which observations were made, *viz.*, 1934, 1935, and 1936. At all stations except Pendleton and Tucson, the critical date as determined by field plantings was earlier than that determined by Hopkins' bioclimatic law.

The date first headed (when about one-tenth of the heads were emerged) was recorded for each variety for each of three seeding dates in the spring in 1934, 1935, and 1936 at each station. When a variety did not head normally the percentage of the heads that emerged was usually recorded. The results from Pullman, Wash., in 1936 are given in Table 2. Based on data similar to these for each year at each station, the varieties were ranked for degree of winterness. The 3-year average rankings for each station are given in Table 3. Data from other experiments on winter survival and date of heading from fall seeding are also included.

Under the wide range of environmental conditions represented at the eight stations, it might be expected that the ranking of the varieties for degree of winterness would be different. As shown in Table 3, such was not the case as the varieties rank in about the same order for degree of winterness as indicated by the habit of growth at each station.

The relations between average degree of winterness, winter hardiness, and date of heading from fall seeding are shown in Fig. 1. It is interesting to note that date of heading from fall seeding and winterhardiness of the winter varieties are not necessarily related to the degree of winterness. Nebraska No. 60 is more hardy and later in heading from fall seeding than Kharkof, yet can be seeded later in the spring than varieties such as Blackhull and Quivira and still produce normal heads. On the other hand, Red Rock ranks next to

TABLE 2.—*Date of heading and maturity for wheat varieties sown on three dates in the spring of 1936 at Pullman, Wash.*

Variety	C. I. No.	Seeded March 4, emerged April 14			Seeded March 19, emerged April 15			Seeded April 15, emerged April 20		
		10% headed	50% headed	50% ripe	10% headed	50% headed	50% ripe	10% headed	50% headed	50% ripe
Ceres	6900	June 10	June 11	July 19	June 12	June 13	July 21	June 14	June 15	July 28
Purplestraw	1915	June 13	June 15	July 26	June 19	June 21	July 29	June 28	July 2	Aug. 10
Nebraska No. 60	6250	June 19	June 21	July 26	June 25	June 27	July 31	Aug. 19	Aug. 29	—
Early Blackhull	8856	June 14	June 15	July 25	June 25	June 28	Aug. 1	Aug. 20	Aug. 29	—
Utah Kanred	11608	June 19	June 21	July 27	June 26	June 28	Aug. 5	Aug. 20	Aug. 29	—
Turkey selection	7366	June 19	June 21	July 28	June 26	June 28	Aug. 5	Aug. 30	—	—
Relief	10082	June 19	June 21	July 28	June 26	June 29	Aug. 7	—	—	—
Tenmarq	6936	June 20	June 21	July 28	July 2	July 7	Aug. 10	Aug. 29	—	—
Turkey selection	10016	June 17	June 19	July 26	July 2	July 6	Aug. 10	—	—	—
Kanred	5146	June 20	June 22	July 28	July 3	July 7	Aug. 10	—	—	—
Quivira	8886	June 19	June 21	July 27	July 6	July 11	Aug. 12	—	—	—
Kharkof	1442	June 22	June 24	July 28	July 6	July 11	Aug. 15	—	—	—
Kanred-Hard Federation	10092	June 16	June 18	July 26	July 7	July 13	Aug. 23	—	—	—
Blackhull	6251	June 21	June 22	July 28	July 12	July 19	Aug. 20	—	—	—
Minturki	6155	June 22	June 24	Aug. 1	July 14	July 20	Aug. 25	—	—	—
Turkey	1558	June 22	June 24	July 29	July 14	July 20	Aug. 31	—	—	—
Cheyenne	8885	June 25	June 28	July 28	July 20	July 29	Sept. 8	—	—	—
Karmont	6700	June 25	June 27	July 30	July 16	Aug. 2	—	—	—	—
Denton	8265	June 28	July 3	Aug. 5	July 18	Aug. 6	—	—	—	—
Harvest Queen	6199	June 23	June 27	Aug. 6	July 19	Aug. 6	—	—	—	—
Yogo	8033	June 25	June 29	July 30	July 29	Aug. 20	—	—	—	—
Minhardi	5149	June 26	July 3	Aug. 12	Aug. 12	Aug. 20	Sept. 5	—	—	—
Kawvale	8180	July 1	July 7	Aug. 10	Aug. 8	Aug. 29	—	—	—	—
Lutescens 0329	8896	July 8	July 13	Aug. 15	Aug. 6	—	—	—	—	—
Odessa	4475	July 7	July 11	Aug. 14	Aug. 8	—	—	—	—	—
Red Rock	5597	July 30	Aug. 8	—	—	—	—	—	—	—

TABLE 3.—*Ranking for degree of winterness of 28 wheat varieties together with data for winter survival and date of heading from normal fall seeding at eight stations.*

Variety or cross	C. I. No.	3-year average ranking for degree of winterness when grown at									Winter survival in percentage of Kharkof*	Date headed†
		Tucson, Ariz.	Denton, Tex.	Manhattan, Kans.	Woodward, Okla.	Lincoln, Nebr.	Akron, Colo.	Pendleton, Ore.	Pullman, Wash.	Average		May
Ceres	6900	1	1	1	1	1	1	1	1	1.0	—	—
Purplestraw	1915	2	2	2	2	2	2	2	2	2.0	—	—
Early Blackhull	8856	4	3	3	4	4	3	3	3	3.4	70.9	17
Utah Kanred‡	11608	3	4	4	3	3	4	4	6	3.9	—	28
Relief§	10082	5	5	5	5	6	5	5	7	5.4	82.1	26
Kanred-Hard Federation	10092	6	8	7	7	7	7	6	8	7.0	89.8	21
Nebraska No. 60	6250	8	7	11	8	12	8	7	5	8.3	107.1	28
Turkey selection	7366	10	12	12	6	5	6	11	4	8.3	75.5	—
Quivira	8886	9	6	8	9	8	9	9	9	8.4	82.6	22
Blackhull	6251	7	9	9	10	10	10	8	10	9.2	78.6	23
Tenmarq	6936	12	11	6	11	11	11	12	11	10.6	83.2	24
Kanred	5146	13	10	13	12	13	12	10	12	11.9	102.9	26
Turkey selection	10016	11	14	10	13	9	13	13	13	12.0	105.9	—
Minturki	6155	14	13	14	15	14	15	15	15	14.4	117.7	27
Kharkof	1442	15	15	16	17	15	16	14	14	15.3	100.0	27
Turkey	1558	17	17	19	14	18	14	16	16	16.4	—	27
Cheyenne	8885	18	16	18	16	17	18	18	17	17.3	102.9	27
Yogo‡	8033	19	18	17	20	16	17	17	19	17.9	119.2	29
Harvest Queen	6199	16	20	15	21	19	20	19	20	18.8	87.4	29
Karmont	6700	23	21	20	19	20	19	20	18	20.0	99.3	28
Minhardi	5149	20	23	21	18	22	25	22	21	21.5	124.1	28
Denton	8265	21	19	22	22	24	21	21	22	21.5	—	27
Kawvale§	8180	22	24	23	23	25	22	24	23	23.3	93.5	26
Red Rock	5597	24	22	25	26	23	23	26	25	24.3	70.0	27
Lutescens 0329‡	8896	25	25	24	24	26	24	25	24	24.6	134.0	—
Odessa	4475	26	26	26	25	21	26	23	26	24.9	117.0	30
Don§	7633	—	—	—	—	27	—	—	27	—	—	—
Durable§	8860	—	—	—	—	27	—	—	28	—	—	—

*For survival data for Red Rock, see Cereal Chem., 16: 208–223, 1939; for Relief and Turkey selection (C. I. 7366), see results from cooperative wheat varietal experiments in the Western Region in 1932 and 1933, respectively, U.S.D.A., B.P.I., Div. C. C. and D. Mimeo. Pubs. 1933 and 1934; for all other varieties, see U. S. D. A. Circs. 378, *1926, and 141, 1930*, and Jour. Amer. Soc. Agron., 30: 399–405, 1938.

†Average for fall seeding at Pendleton, Ore., in 1933 and 1934, and at Lincoln, Nebr., in 1937.

‡Degree of winterness rating based on 2 years' results.

§Degree of winterness rating based on 1 year's results.

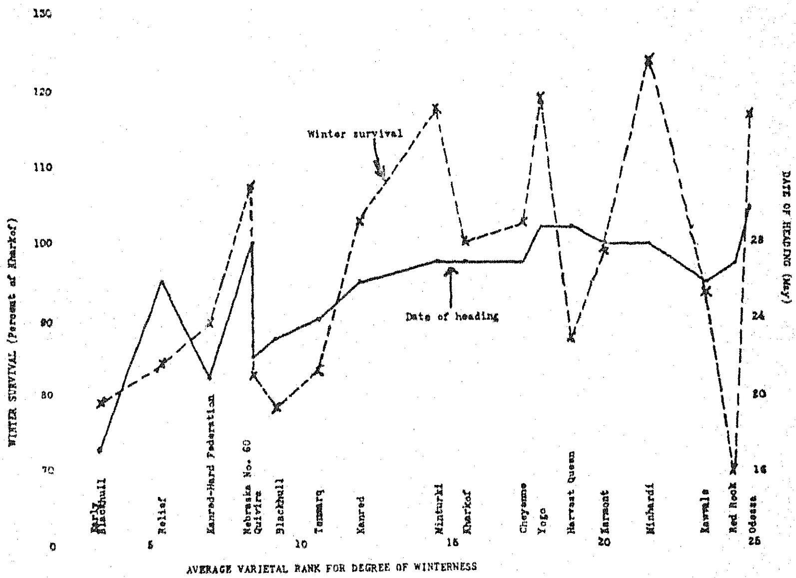

FIG. 1.—Relation between degree of winterness from spring seeding and winterhardness from fall seeding and between degree of winterness from spring seeding and date of heading from fall seeding of several winter wheat varieties.

Odessa in degree of winterness but is no more hardy than Early Blackhull and is earlier in heading from fall seeding than Nebraska No. 60.

Several of the varieties (Early Blackhull, Kanred-Hard Federation, Quivira, Tenmarq, and Blackhull) included in this study are early maturing and are able to produce heads from later spring seeding than varieties such as Kharkof, but none of these early maturing varieties approach Kharkof in hardiness.

SUMMARY

Growth habit as determined from spring seedings of 28 wheat varieties was studied at eight experiment stations in the years 1934 to 1936, inclusive. Data on earliness from fall sowing and winter survival from other tests are included in order to study their relation with the degree of winterness.

The varieties rank in about the same order for degree of winterness when grown at each of the stations.

Degree of winterness is not closely related to time of heading from fall seeding or to winterhardiness in the varieties studied.

None of the early varieties were as hardy as most of the late ones. However, a few of the late varieties were no more hardy than earlier maturing ones.

THE EFFECT OF HEIGHT AND FREQUENCY OF CUTTING ALFALFA UPON CONSEQUENT TOP GROWTH AND ROOT DEVELOPMENT[1]

S. C. HILDEBRAND AND C. M. HARRISON[2]

THE increased acreage of alfalfa in the north central section of the United States, particularly in Michigan, is partially due to its use as a pasture crop during the hot summer months of July and August. During this period conditions of low rainfall and high temperatures usually prevail and native bluegrass pastures are largely dry and dormant. Experiments conducted at the Michigan Agricultural Experiment Station at East Lansing show that alfalfa or a mixture of alfalfa and smooth brome grass, because of the drought resistance of these plants, will furnish more green feed during the hot months than any other combination of perennial plants yet tried. Alfalfa has proved to be highly productive, palatable, nutritious, and reasonably enduring provided proper management practices are followed.

Research has shown that cutting at immature stages of growth may result not only in damage to the stand, but also in a reduction of the amount of new growth produced. Graber, et al. (2)[3] found that frequent cutting of alfalfa at immature stages of growth lowered the productivity and vigor of the plants, favored weed encroachment, and accelerated both winter and summer damage to the stand, all of which was primarily the result of depleted food reserves in the roots.

Albert (1), Willard (6), Nelson (4), and Kiesselbach and Anderson (3) substantiate the findings of Graber. Experiments have also shown that alfalfa should be pastured at a higher level than is generally practiced on pasture plants in order to secure the best yields and allow for adequate storage of food reserves in the roots.

With the above facts in view the experiment described here was set up in the greenhouse at East Lansing, Mich., to study the effect of the height and frequency of cutting alfalfa upon the production of "recovery" growth and root development, and to obtain an indication as to the proper height-level of grazing alfalfa for maximum production of feed and maintenance of the stand.

EXPERIMENTAL PROCEDURE

In September, 1937, several hundred Hardigan alfalfa plants were dug from a 1-year-old alfalfa field. These plants were brought into the greenhouse, selected for uniformity, and transplanted into sand cultures in 10-inch clay pots, eight plants per pot. They were kept growing until April, 1938, by frequent watering and the application of a complete nutrient solution at regular intervals.

On April 13 the cultures were selected at random and arranged in five sets of nine each, to be cut back to 1, 3, 6, 9, and 12 inches, respectively. Three of each of the sets of nine were cut at weekly, three at biweekly, and three at monthly

[1]Contribution from the Section of Farm Crops, Michigan Agricultural Experiment Station, East Lansing, Mich. Jour. Article 368 (N. S.). Received for publication July 3, 1939.

[2]Graduate Student and Research Associate, respectively.

[3]Figures in parenthesis refer to "Literature Cited", p. 799.

intervals. In addition, nine cultures were selected as final checks and three selected as representative of the group to show the condition of the plants at the beginning of the experiment.

Beginning on April 13, the plants were cut for a period of 12 successive weeks at their respective height levels and intervals, the checks being left uncut. At the end of the 12 weeks all plants, including the checks, were completely defoliated once each week for four successive weeks in an attempt to measure root storage by the amount of recovery growth made between defoliations. The cultures were then allowed to recover for two weeks and the sand washed from the roots. Green and dry weights were taken from each cutting and for the tops and roots at the end of the experiment.

RESULTS

The tops and roots of these three representative cultures were separated and the green and dry weights recorded in Table 1. (See Fig. 1.)

TABLE 1.—*The yield of tops and roots of alfalfa plants before cutting treatments were begun.*

Culture No.	Tops		Roots	
	Green weight, grams	Dry weight, grams	Green weight, grams	Dry weight, grams
1	120.00	35.00	116.70	27.45
2	121.00	27.50	90.80	26.45
3	115.00	27.00	128.45	28.40
Mean weight, grams	118.67	29.17	111.98	27.43

EXPERIMENT 1. YIELD OF TOP GROWTH

The comparable effect of cutting alfalfa back to 1, 3, 6, 9, and 12 inches from the sand upon the yield of top growth is shown in Tables 2, 3, and 4 for weekly, biweekly, and monthly cutting intervals, respectively.

More top growth was produced at first when the plants were cut at 1- and 3-inch levels (Table 2), but after several cuttings were made the reverse was true. The alfalfa plants which were cut to low levels made an upright growth, while the plants cut to the 9- and 12-inch levels made a large portion of their growth from the crown but produced little growth above the cutting level.

Plants cut at the 6-inch level produced the most "recovery" growth, but the yields were not significantly greater than those cut at the 3-, 9-, or 12-inch levels. Cutting at the 1-inch level, however, gave significantly lower yields than any of the other treatments.

Differences in total yield between the high and low levels of cutting were large (Table 3). The amount of "recovery" growth was significantly larger when the alfalfa was cut at a 6-inch level than when cut at 1-, 3-, or 12-inch levels.

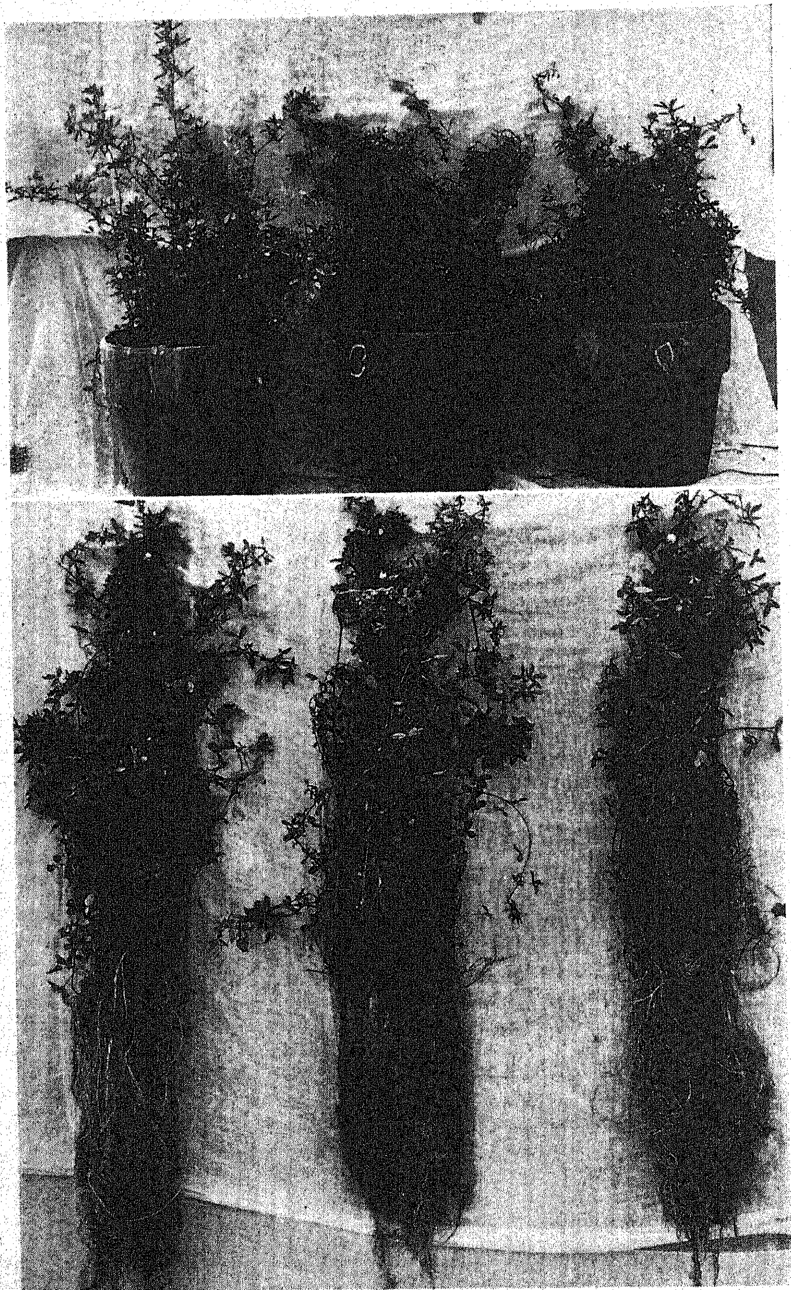

FIG. 1.—Alfalfa cultures at the beginning of the experiment, April 13, 1938. *Above*, representative cultures used in the experiment. *Below*, the same cultures after washing sand from the roots.

TABLE 2.—*The effect of weekly cuttings at various heights upon the dry matter yield of tops of alfalfa, average of three cultures except for checks.**

Date of cutting, 1938	Dry matter in grams when cut at					Av. of nine checks, grams
	1 inch	3 inches	6 inches	9 inches	12 inches	
April 13	17.00	19.00	13.33	9.00	5.17	
April 20	1.26	1.64	0.93	0.51	0.39	
April 27	1.34	2.45	1.93	0.60	0.44	
May 4	1.42	2.53	1.96	1.39	0.87	
May 11	0.68	1.30	1.81	1.00	1.20	
May 18	0.64	0.77	1.40	1.43	1.39	
May 25	1.05	1.69	2.45	2.23	2.23	
June 1	0.72	1.75	2.29	2.13	1.64	
June 8	0.64	2.53	3.28	3.26	1.70	
June 15	0.37	3.18	3.69	3.51	4.70	
June 22	0.51	2.86	2.57	1.78	2.35	
June 29	0.47	3.97	5.00	3.87	5.01	
July 6†	2.94	19.40	37.50	54.30	72.50	79.53
Total yield	29.03	63.07	78.14	85.01	99.59	79.53
"Recovery" growth made above the cutting level‡	9.10	24.67	27.31	21.71	21.92	

*The yield at each cutting date represents the average yield of tops from all of the three cultures under each treatment. The differences required for significance were calculated by use of an analysis of variance (5). This statement also applies to Tables 3, 4, 5, 6, 7, and 8.

†All of the cultures were completely defoliated on this date.

‡Yields on April 13 and July 6 were disregarded in securing "recovery" growth. On April 13 the plants were first cut down to their respective height levels and on July 6 the plants were completely defoliated. No yields of tops above the cutting level were taken on July 6. Yield differences required for significance between amounts of "recovery" growth: Odds of 19:1 = 11.01 grams; odds of 99:1 = 16.01 grams.

TABLE 3.—*The effect of biweekly cuttings at various heights upon the dry matter yield of tops of alfalfa, average of three cultures except for checks.*

Date of cutting, 1938	Dry matter in grams when cut at					Av. of nine checks, grams
	1 inch	3 inches	6 inches	9 inches	12 inches	
April 13	19.00	17.50	14.00	9.17	4.07	
April 27	5.06	3.56	4.03	2.82	1.36	
May 11	3.35	4.03	4.60	3.75	3.81	
May 25	3.00	2.77	3.97	3.81	3.22	
June 8	3.71	6.20	8.03	7.48	5.54	
June 22	3.10	5.83	7.73	5.37	6.83	
July 6*	8.17	24.53	48.83	63.93	77.57	79.53
Total yield	45.39	64.42	91.19	96.33	102.40	79.53
"Recovery" growth made above the cutting level†	18.22	22.39	28.36	23.23	20.76	

*All cultures were completely defoliated on this date.

†Yields on April 13 and July 6 disregarded in securing "recovery" growth. On April 13 the plants were first cut down to their respective height levels and on July 6 the plants were completely defoliated. No yield of tops above the cutting level taken. Yield differences required for significance between amounts of "recovery" growth: Odds of 19:1 = 5.28 grams; odds of 99:1 = 7.68 grams.

When cut at monthly intervals more "recovery" growth was obtained at the 1-inch than at any of the higher levels of cutting (Table

TABLE 4.—*The effect of monthly cuttings at various heights upon the dry matter yield of tops of alfalfa, average of three cultures except for checks.*

Date of cutting, 1938	Dry matter in grams when cut at					Av. of nine checks, grams
	1 inch	3 inches	6 inches	9 inches	12 inches	
April 13	23.17	18.83	13.67	10.67	3.37	
May 11	15.27	12.87	15.37	10.50	2.50	
June 8	13.80	14.23	11.07	14.75	9.50	
July 6*	26.67	37.80	59.67	77.27	69.07	79.53
Total yield	78.91	83.73	99.78	113.19	84.44	79.53
"Recovery" growth made above the cutting level†	29.07	27.10	26.44	25.25	12.00	

*All cultures were completely defoliated on this date.

†Yields on April 13 and July 6 disregarded in securing "recovery" growth. On April 13 the plants were first cut down to their respective height levels and on July 6 the plants were completely defoliated. No yield of tops above the cutting level taken. Yield differences required for significance between amounts of "recovery" growth: Odds of 19:1 = 13.47 grams; odds of 99:1 = 19.6 grams.

4). The alfalfa cut at the 12-inch level gave significantly lower yields than that cut at the 1-, 3-, or 6-inch levels, due to the maturity of the plants and the lack of vegetative growth.

TABLE 5.—*Summary of the effect of height and interval of cutting upon the "recovery" growth of alfalfa in grams dry weight, Tables 2, 3, and 4 corrected to 8 weeks' treatment, average of three cultures.**

Interval of cutting	Dry matter in grams when cut at				
	1 inch	3 inches	6 inches	9 inches	12 inches
Weekly	7.75	14.66	16.05	12.55	9.86
Biweekly	15.12	16.56	20.63	17.86	13.93
Monthly	29.07	27.10	26.44	25.25	12.00

*Yield differences required for significance between amounts of "recovery" growth: Odds of 19:1 = 8.61 grams; odds of 99:1 = 11.66 grams.

In order to compare the recovery yields obtained under each cutting interval over a comparable growing period, only those yields for the eight weeks' period April 13 to June 8 are given in Table 5. The amount of "recovery" growth increased as the time interval of cutting increased with the exception of the cultures cut at 12 inches (Table 5). Not all of these increases were significant. The weekly cuttings gave significantly lower yields than the monthly cuttings except for the plants cut at the 12-inch level. At the 1- and 3-inch cutting levels, significantly lower yields were obtained from biweekly over monthly cuttings.

EXPERIMENT II. FOOD RESERVES IN THE ROOTS

To determine the food storage in the roots of alfalfa, the plants in each culture were completely defoliated and the stored food was measured in terms of new top growth produced. At the end of the experiment the dry weight of the roots from each culture was determined.

The cultures which were previously cut for 12 weeks at various heights and intervals were completely defoliated each week for four successive weeks. Yields were taken and are recorded in Table 6.

TABLE 6.—*Growth dry weight in grams made in weekly periods following complete defoliation, average of three cultures except for checks.*

Date of defoliation	Dry weight in grams when cut at					Av. of nine checks, grams
	1 inch	3 inches	6 inches	9 inches	12 inches	
Previous Cuttings Made Weekly						
July 13	0.16	1.12	1.82	2.56	3.36	3.69
July 20	0.01	1.33	2.12	3.93	6.13	5.59
July 27	dead	0.69	1.20	2.70	4.07	5.24
Aug. 3	dead	0.33	0.49	1.64	1.90	4.07
Total	——	3.47	5.63	10.83	15.66	18.59
Previous Cuttings Made Biweekly						
July 13	0.32	0.91	1.58	2.07	2.12	3.69
July 20	0.26	1.55	2.03	4.00	4.63	5.59
July 27	0.03	0.88	1.60	2.93	4.00	5.24
Aug. 3	dead	0.58	0.86	1.61	2.35	4.07
Total	——	3.92	6.07	10.61	13.10	18.59
Previous Cuttings Made Monthly						
July 13	1.36	1.56	1.62	3.23	3.23	3.69
July 20	1.81	2.76	3.40	4.57	5.57	5.59
July 27	0.92	1.73	1.87	3.77	3.70	5.24
Aug. 3	0.49	0.91	1.18	1.73	2.37	4.07
Total*	4.58	6.96	8.07	13.30	14.87	18.59

*Totals are not given for the 1-inch cultures cut weekly and biweekly because the plants died before four complete defoliations were made. The plants being dead, yields from these cultures were not included in the analysis of variance. Yield differences required for significance between total amounts of "recovery" growth: Odds of 19:1 = 5.92 grams; odds of 99:1 = 8.01 grams.

As the height level of the previous cutting increased, the yield of tops, following complete defoliation, increased. This holds true for weekly, biweekly, and monthly cutting intervals. Alfalfa cut at the 1-inch level in both the weekly and biweekly cutting intervals died before four complete defoliations were made. Plants cut at the 1- and 3-inch levels, under each time interval gave significantly lower yields than the plants cut at the 9- and 12-inch levels or the check cultures.

Following four weekly complete defoliations the plants were allowed to recover for two weeks and the sand washed from the roots. The tops and roots were separated and dry weights recorded in Tables 7 and 8, respectively.

The condition of the tops and roots of the plants after being subjected to the various cutting treatments is shown in Figs. 2, 3, and 4 for weekly, biweekly, and monthly cutting intervals, respectively.

TABLE 7.—*Dry weight of tops of alfalfa after being allowed to recover for two weeks after four weekly complete defoliations, average of three cultures except for checks.**

Previous interval of cutting	Dry weight in grams at previous height of cutting of					Av. of nine checks, grams
	1 inch	3 inches	6 inches	9 inches	12 inches	
Weekly	Dead	0.97	0.37	6.00	11.23	13.47
Biweekly	Dead	2.77	1.98	6.30	9.47	—
Monthly	1.17	3.13	3.87	10.27	9.67	—

*Yield differences required for significance between amounts of recovery growth: Odds of 19:1 = 5.61 grams; odds of 99:1 = 7.60 grams.

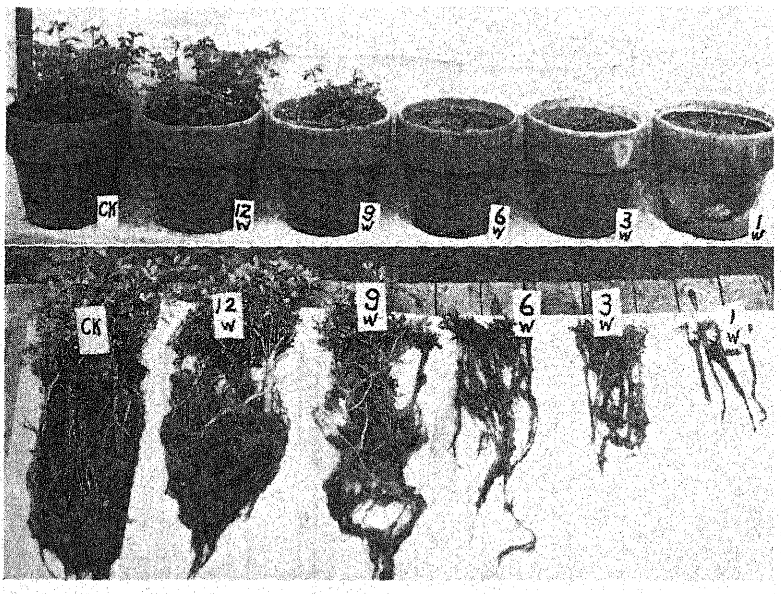

FIG. 2.—Growth response and condition of roots of plants cut at weekly intervals, August 16, 1938. *Above*, growth response after two weeks following four successive complete defoliations of cultures cut back weekly over a period of 12 weeks to the indicated heights. *Below*, the same as above after washing sand from the roots. Reading left to right: Check, 12-inch, 9-inch, 6-inch, 3-inch, and 1-inch levels of cutting. Note the lack of root development of the plants cut at the 1-, 3-, and 6-inch levels along with the dead roots present. The 9- and 12-inch cutting levels and the check cultures have a good healthy root system, although that of the plants cut at the 9-inch level is decidedly smaller than those of the other two.

DISCUSSION

Carbohydrate food storage in the roots of alfalfa plants depends primarily upon top growth. As carbohydrate materials are manufactured through photosynthesis they are either utilized by the growing plant in producing new plant parts or stored for future use. As

TABLE 8.—*Dry weight of alfalfa roots at the end of the experiment, average of three cultures except for checks.**

Previous interval of cutting	Dry weight in grams with height level of cutting prior to complete defoliation					Av. of nine checks, grams
	1 inch	3 inches	6 inches	9 inches	12 inches	
Weekly	3.22	8.76	11.46	22.31	39.39	——
Biweekly	5.21	13.21	17.14	24.16	30.64	——
Monthly	11.09	18.24	20.00	33.79	38.88	——
						41.52

*Yield differences required for significance between weight of roots: Odds of 19:1 = 11.03 grams; odds of 99:1 = 14.93 grams.

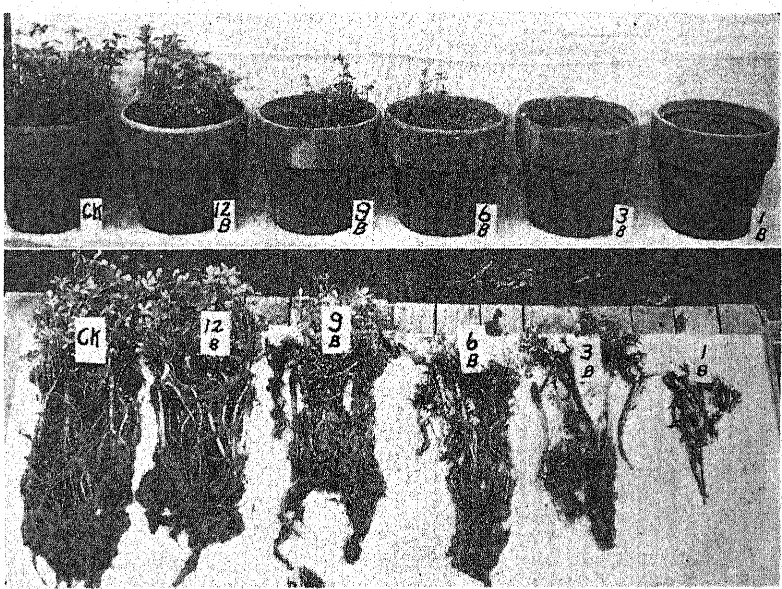

FIG. 3.—Growth response and condition of roots of plants cut at biweekly intervals, Aug. 16, 1938. *Above*, growth response after two weeks following four successive complete defoliations of cultures cut back biweekly over a period of 12 weeks to the indicated height. *Below*, the same as above after washing sand from the roots. Reading left to right: Check, 12-inch, 9-inch, 6-inch, 3-inch, and 1-inch levels of cutting. Note the lack of response of the plants cut at the 1-inch level as compared with those cut at the 3-inch level. Those cut at 6- and 9-inch levels show medium response, but are not comparable to the 12-inch level or check. The same general statement holds true for the roots.

alfalfa plants mature, growth processes slow up and more materials are manufactured than needed, the surplus being stored principally in the roots.

Alfalfa plants with a small amount of leaf tissue will develop only a small root system. It is evident that not as much total food can be stored in a small root as in a large one. If the top growth is com-

pletely removed, carbohydrate manufacture stops, hence any new growth initiated must be at the expense of reserves. If the tops are removed frequently, allowing for little or no food storage, the reserves will soon become depleted to such an extent that no new growth will be initiated and as a result the plant becomes weakened and dies.

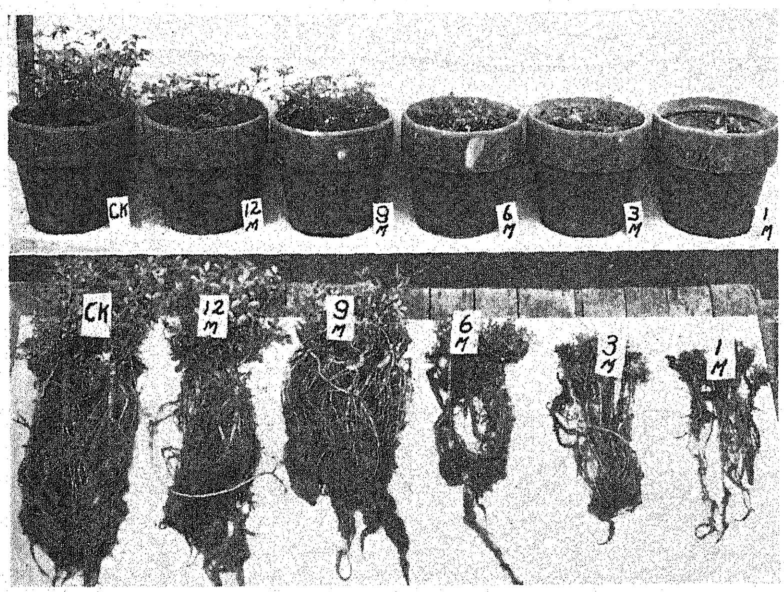

FIG. 4.—Growth response and condition of roots of plants cut at monthly intervals, Aug. 16, 1938. *Above*, growth response after two weeks following four successive complete defoliations of cultures cut back monthly over a period of 12 weeks to the indicated height. *Below*, the same as above after washing sand from the roots. Reading left to right: Check, 12-inch, 9-inch, 6-inch, 3-inch, and 1-inch levels of cutting. Small responses were made by the alfalfa cut at the 1-, 3-, and 6-inch levels, but they do not compare favorably with that made by the plants cut to higher levels. The same is true for the roots. Note the dead roots of the plants cut at the 1-, 3-, and 6-inch levels, especially those cut at the 1-inch level, as compared with the well-developed root system of the check plant and those cut at the 9- and 12-inch levels.

When alfalfa plants are cut in such a manner that a large portion of the top growth remains, carbohydrate manufacture may continue. After several frequent, successive and complete defoliations plants with large root systems, which contain a large amount of reserve food, continue to initiate new growth. Eventually the reserves of plants treated in this manner will become depleted if close cutting is continued.

Plants cut weekly to 1-inch levels made very little recovery growth following complete defoliation and after two successive defoliations, one week apart, all of the plants were dead. This would indicate that the cutting treatment previous to complete defoliation had allowed very little storage of reserve materials. The plants which were cut

biweekly to 1-inch levels responded in a similar manner but withstood a third defoliation before the plants died, indicating that, although the storage of reserves was low, it was somewhat higher than that of the plants cut weekly. The amount of recovery growth following complete defoliation was considerably greater in the plants cut biweekly at the 1-inch level than those cut weekly at the same level. The plants cut to the 1-inch level at monthly intervals not only survived four complete defoliations, but the production of new growth was far greater on any given date than that of the plants previously cut to 1 inch either weekly or biweekly. This would indicate that there was a larger amount of storage in plants cut at monthly intervals than those cut at weekly or biweekly intervals. In general, these observations hold true for all of the cultures with the exception of the plants cut at the 12-inch level.

In all cases except the plants cut weekly and biweekly at the 1-inch level, the first defoliation resulted in less production of "recovery" growth in a week than did the second defoliation. After the second defoliation the trend is downward in practically all cases, indicating that the storage supplies were rapidly diminishing.

CONCLUSIONS

1. Cutting alfalfa frequently and close to the crown resulted in depletion of the food reserves in the roots and a marked decrease in yield of hay and vigor of the plants.

2. Alfalfa cut frequently at a high level (12 inches) resulted in decreased yields owing to loss of leaves due to the maturity of the plant and a lack of vegetative growth.

3. Alfalfa remained vigorous when cut back to a 6-inch level either biweekly or monthly. At an interval of one week between cuttings the plants failed to produce sufficient stored food to maintain the plant over unfavorable periods of growth.

4. Cutting back to the 9-inch level gave good yields of top growth and roots when cut at weekly or biweekly intervals, whereas the monthly interval of cutting allowed the plants to mature, resulting in a retardation of vegetative growth.

5. Although cutting at 12 inches resulted in an abundance of food storage, the yield of top growth above the cutting level was relatively low due to the maturing of the tops below the cutting level.

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SAMPLING INTENSITY IN VEGETATION SURVEYS MADE BY THE SQUARE-FOOT DENSITY METHOD[1]

DAVID F. COSTELLO AND GRAYDON E. KLIPPLE[2]

METHODS of making surveys of range land vegetation have been evolving slowly for a period of more than 30 years. Since the beginning, determination of density or spread of vegetation above the ground has been an integral part of survey procedure. Originally, density was estimated by the system common to the reconnaissance method of range surveying (3).[3] More recently a method of determining density known as the square-foot density or point-observation-plot method has been developed by Stewart and Hutchings (4), and this method is now optional in standard range survey instructions (3). Questions and comments which have arisen as a result of the use of the optional square-foot density method in range surveys have emphasized a need for specific information on sampling intensity as reflected in number of plots required for an estimate within given limits of accuracy.

This paper, based on sample plot data recorded from all major range vegetation types in Colorado, Wyoming, and the Black Hills region of South Dakota, deals with sampling intensity in relation to reliability of mean densities and forage factors secured by the square-foot density method. It also presents the relationships between number of plots required for a reliable sample and (a) size of area sampled, (b) vegetation type, and (c) adequacy of sampling as determined by the purpose of the survey.

SOURCE AND NATURE OF THE DATA

A very considerable mass of data, obtained through the use of the square-foot density method of making range surveys, has been assembled by the Rocky Mountain Forest and Range Experiment Station. Observations on 4,620 plots were obtained in a general survey of range conditions throughout Colorado and Wyoming and in the Black Hills of South Dakota in October 1935. A forage inventory of Colorado and Wyoming, started in the spring of 1936, resulted in observations on 44,123 sample plots by November 1938. These data were supplemented by 24,476 sample plots which were established by various state and federal agencies[4] under careful supervision and coordination during 1936 and 1937.

The basic data on all plots were recorded on Form 764b of the instructions for range surveys (3) or on similar forms. Species were listed by vegetation types and their densities were recorded directly in square feet or fractions thereof for each plot. Plot locations within any type area were determined by throwing a stone into the type to locate the first plot and by stripping or grid-ironing at a predetermined sampling interval until the necessary number of plots was established.

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[1]Contribution from the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Received for publication July 10, 1939.

[2]Associate Forest Ecologist and Junior Agricultural Economist, respectively.

[3]Figures in parenthesis refer to "Literature Cited", p. 810.

[4]The agencies participating in this cooperative project were the Forest Service, Resettlement Administration, Soil Conservation Service, of the U. S. Dept. of Agriculture; the Division of Grazing of the U. S. Dept. of Interior; Colorado State College of Agriculture and Mechanic Arts; and the University of Wyoming.

For possible future reference, plots were located by section, township, and range and in most instances designated on base maps. Plot data were accompanied by type descriptions and comments on forage utilization, range conditions, class of livestock, and erosion.[5]

METHODS OF ANALYSIS

SORTING OF PLOT DATA

The data from individual plots were grouped by vegetation types or portions of vegetation types within geographic localities, national forests, management units, or some similar area. When excessive numbers of plots were available from a vegetation type within a given area a random sample of 500 to 2,000 plots was chosen for statistical analysis. Plots representing small areas of exceedingly high or low densities within broad types of average density were retained in all instances since they were an expression of type heterogeneity.

In computing the number of plots required for varying degrees of accuracy on large areas, plots were combined without reference to range conditions. For small areas, such as would be represented by management units, problem areas, and sub-ranch units, plot series were sorted into three groups depending on whether or not the range condition was considered to be poor, average, or good. Data of the several years were not thrown together.

COMPUTATIONS OF DENSITIES AND FORAGE FACTORS

Plot density was obtained by adding the species densities for each plot. The species densities were added to obtain total species density for a series of plots within a vegetation type. Average density of each species in the type was obtained by dividing the total density of each species by the number of plots in the series. Mean density of the type was secured by dividing the sum of the plot densities by the total number of plots.

The forage factor was computed for each plot by multiplying the density of each species by its percentage palatability (2, 3) and adding the products thus obtained. By pointing off two decimal places to the left the forage factor was expressed in terms of forage acres per surface acre. The forage factor is a relative figure and may be used in the comparison of grazing capacities of different areas without reference to grazing capacity in terms of animal months.

RESULTS AND DISCUSSION

RELATION BETWEEN SAMPLING INTENSITY AND STATISTICAL ACCURACY

The number of plots required to give a mean density or a mean forage factor of any desired degree of accuracy was calculated by transposing the formula for the standard error of a mean to the following form (1): $N=\left(\frac{\sigma}{\sigma_M}\right)^2$, in which the standard deviation (σ)

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[5]In the square-foot density method, density is estimated on circular plots, 100 square feet in area. The unit of estimation is a square-foot of area completely covered by vegetation when viewed from directly above. When vegetation does not completely cover the ground, individual plants are mentally amassed into square-foot units of total (10/10) density. The number of square foot units are counted for each species on a plot and recorded in square feet or fractions thereof on the examiner's field data sheet (Form 764b). The examiner's density concept is frequently checked by picking the vegetation and placing it at 10/10 density in a wire frame 1 foot square.

was determined from the plot data and the standard error of the mean (σ_M) was given an arbitrary value depending on the accuracy desired. Thus, to provide an index of the number of plots required for accuracies varying from 80 to 99%, standard deviations were computed from samples of 300 to 1,000 plots selected from each of the main vegetation types in Colorado and Wyoming. Allowable errors of 1, 2, 3, 4, 5, 10, and 20% of the mean were substituted for σ_M in the above formula, and N was then computed in each instance. The results of this computation for the sagebrush type in northwestern Colorado are shown graphically in Fig. 1. Values in Fig. 1 are shown at the 5% level of significance (odds of 19:1). This level of significance is used throughout this paper.

The law of diminishing returns applies to sampling of density and grazing capacity. Increase or decrease in sampling error is proportional to the square root of the number of plots. For example, in order to double the accuracy (decrease the error by one-half) the number of plots must be quadrupled. Thus, Fig. 1 indicates that 48 plots examined in the sagebrush type in northwestern Colorado will give a survey accuracy of 90% for density, while 193 plots will only increase the accuracy to 95%. Slight discrepancies from the ratio mentioned

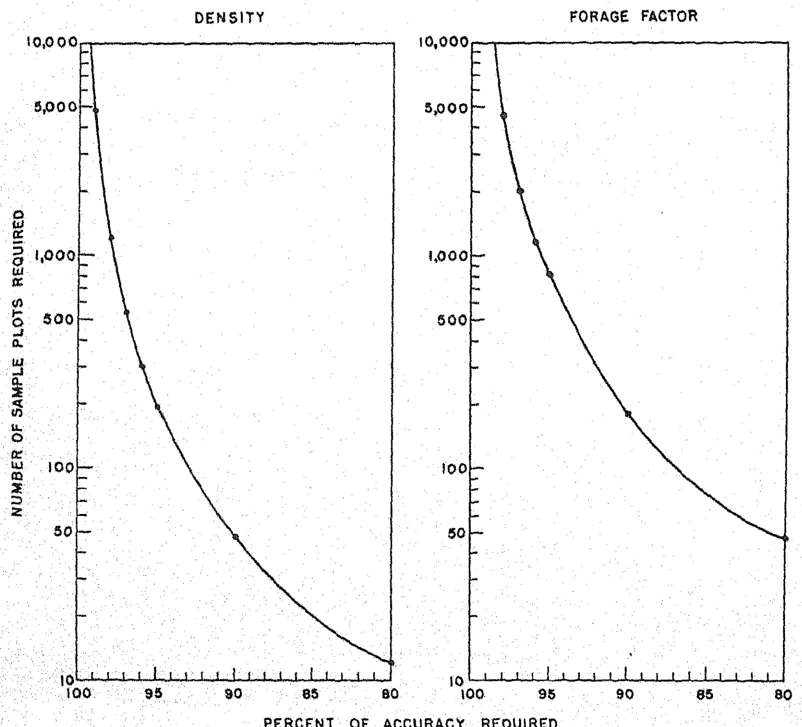

FIG. 1.—Number of plots required for different degrees of sampling accuracy for the sagebrush type in northwestern Colorado.

above occur in actual computation as a result of rounding off numbers. Similar diagrams, constructed from data secured in any vegetation type, will show the same relationships between number of plots and statistical accuracy.

It is obvious from Fig. 1 that accuracies exceeding 95% require an excessive number of plots entailing a cost of field work and analysis which is prohibitive and unwarranted in view of the errors introduced in surveys by factors other than sampling. For example, the examiner's error in using the square-foot density method is seldom less than 5%. Seasonal and yearly fluctuations from the average density often exceed 20% and may even be much greater in years of drought or seasons of heavy rainfall. The palatabilities used in computing grazing capacities are approximations and vary from season to season and from one forage type to another. Consequently, sampling intensities which give an accuracy of 80% should be adequate for all practical purposes in range surveys.

RELATION BETWEEN VEGETATION TYPE AND SAMPLING INTENSITY

When the transposed formula for the standard error of a mean is used to compute the number of plots required to give reliable estimates of either density or forage factor, relatively wide variations between vegetation types are found to exist. These variations are exemplified in Table 1 by the numbers of plots necessary to sample both density and the forage factor for broad areas of representative forage types in Colorado and Wyoming, within 20, 10, and 5% of the probable true mean (80, 90, and 95% accuracy).

It is evident from these data that the intensity of sampling necessary to secure a given degree of accuracy must vary not only from type to type but within types as they occur in different localities. For instance, the five examples given as representative of the Great Plains short grass type show, in the 80% column, a variation ranging from 12 to 26 plots required for a reliable density estimate and 18 to 44 plots for the forage factor. This variability between types and between portions of the same type is largely the result of the different degrees of heterogeneity in vegetation that occur from place to place.

The number of plots necessary to sample the forage factor tends to be larger than the number necessary to sample density. This is the result of greater relative dispersion of forage factors about their means than is the case with the relative dispersions of densities around their means. In Table 1 the greasewood type is the only type requiring fewer plots to sample forage factors than are necessary to sample densities. Densities in a greasewood type are widely dispersed on randomly selected plots owing to the frequent occurrence of barren areas and the occasional occurrence of greasewood or other plants with high densities. Forage factors, however, tend to be less widely dispersed because the majority of plants commonly found in greasewood types are of zero or at most very low palatability. The occasional grasses or other plants of high palatability that may be present usually contribute little to the density. Since the forage factor is the product of density and palatability, the multiplication of low palatabilities by the high densities derived mainly from greasewood and

TABLE 1.—*Number of plots necessary to give reliable estimates of density and forage factor for different degrees of accuracy in representative forage types in Colorado and Wyoming.*

Forage type	Standard type number	Location	Density, number of plots required for accuracy of			Forage factor, number of plots required for accuracy of		
			80%	90%	95%	80%	90%	95%
Mt. bunchgrass...	1	National forests in Colorado	18	72	288	26	104	414
Plains short grass..	1	Converse County, Wyoming	26	106	423	44	174	697
Plains short grass..	1	Northeastern Colorado	12	46	185	19	75	299
Plains short grass..	1	Weld Co. (in N. E. Colorado)	14	54	217	18	72	288
Plains short grass..	1	Baca Co. (in S. E. Colorado)	21	85	340	30	120	480
Plains short grass..	1	Cheyenne Co. (in eastern Colorado)	17	66	256	24	95	381
Saltbush.........	13	Sweetwater Co. (in S. W. Wyoming)	27	110	438	36	142	569
Sagebrush........	4	Moffat Co. (in N. W. Colorado)	12	48	193	46	182	729
Sagebrush........	4	National forests in Colorado	15	59	235	75	298	1,192
Sagebrush........	4	Sweetwater Co. (S. W. Wyoming)	25	100	399	42	170	678
Annual weed......	18	Weld Co. (N. E. Colorado)	33	132	528	56	225	902
Oakbrush........	5	National forests (S. W. Colorado)	22	90	360	47	186	744
Greasewood......	14	Moffat Co. (in N. W. Colorado)	35	139	557	34	134	538
Greasewood......	14	Sweetwater Co. (S. W. Wyoming)	65	260	1,039	52	207	826
Conifer..........	6	National forests in Colorado	20	80	322	68	273	1,091
Dry Mt. meadow..	2D	National forests in Colorado	19	76	303	51	203	812
Wet Mt. meadow..	2W	National forests in Colorado	22	87	347	38	152	606

other shrubby species, and the multiplication of low densities by high palatabilities derived principally from grasses, causes forage factors to be grouped about their mean closer than is the case with density values.

The data presented in Table 1 indicate also that an approximate maximum limit can be established for the probable number of plots necessary to sample any broad range type within a given degree of accuracy. Thus, 33 plots will sample the density and 56 plots will sample the forage factor with 80% or greater accuracy in all but two of the types listed. These figures, of course, apply to the types as a whole. Specific portions of any type may show either more or less heterogeneity than the average area within the type. If uniform accuracy is desired in a survey involving different vegetation types, different sampling intensities usually will be required for each type.

RELATION BETWEEN AREA AND SAMPLING INTENSITY

The number of plots needed for a reliable estimate of either density or forage factor is not proportional to the area of the type to be sampled. Apparently, the number of plots needed is mostly dependent upon heterogeneity of the vegetation cover and is related to area only as heterogeneity is related to area.

The dispersion of plot values found within a portion of a type may be as great as the dispersion within the entire type. Any two plots located at random in a forage type may represent the upper and lower limits of density or forage factor that will be encountered. The first of the two plots may fall on barren soil and the second in dense vegetation, irrespective of the size of area in which they are chosen.

Table 2 presents the accuracy obtained when samples of 100 plots each were selected at random for areas of increasing size in the short

TABLE 2.—*Accuracy obtained by samples of 100 plots on areas of different size.*

Size of area, sq. miles	Percentage of accuracy obtained	
	Density	Forage factor
1	93.23	90.87
2	92.66	91.24
4	94.01	92.02
8	90.82	88.39
12	89.26	88.42
16	91.72	88.24
20	90.60	86.90
100	89.65	86.78
10,000	91.85	85.79

grass type in northeastern Colorado. The percentages of accuracy obtained for density and for the forage factor were computed for samples of 100 plots selected for each area. The accuracy of density estimates falls in the narrow range of 89.26 to 94.01%. Accuracy of the forage factor estimates shows a slightly greater range, 85.79 to 92.02%. The percentages of accuracy obtained are significantly uniform in both cases. The accuracy of the forage factor appears to

diminish with increasing size of area. Data from intensive surveys are not available to test whether or not the trend observed would appear in similar samples taken in other localities and in other types.

CONDITIONS AFFECTING SAMPLING INTENSITY WITHIN VEGETATION TYPES

Type heterogeneity.—In surveys designed to secure data for range management purposes, plot transects, usually consisting of 3 to 20 plots, are located in each vegetation type or subtype within a section, or a management unit. Grazing capacities are then computed for each series of plots. Thus, the basis for determining the intensity of sampling to be used in a detailed survey lies in the data obtained from each localized area of a vegetation type rather than in data consisting of a composite sample of plots taken in many portions of the entire type. Any specific portion of a type may require a different number of plots for a given accuracy than any other portion of the type. Hence, in order to survey a range area with statistical uniformity, the required number of plots would have to be determined for each portion of a type on which a plot transect was taken. This is impractical when large areas are being surveyed intensively.

The practical solution to this problem is to determine the number of plots that would be required to sample various portions of each vegetation type on which a plot transect would be taken. The numbers of plots required for different transects can be arranged in a cumulative frequency distribution to show both the number and percentage of areas within a type which require "*more than*" or "*less than*" a given number of plots for a reliable sample.

In a study of type heterogeneity in the mountain bunchgrass type on the east slope of Colorado, the results shown in Table 3 were secured. The numbers of plots required for 80% accuracy on each of 25 areas within the type were assembled cumulatively and the frequencies were reduced to percentages. The table indicates that 35 plots will sample 8% of the areas with 80% accuracy, 45 plots will sample 28% of the areas, and so on. Information of this kind may be used as a basis for establishing the average number of plots for each transect that would be commensurate with the purpose of the survey.

TABLE 3.—*Cumulative distribution of 25 transects in the mountain bunchgrass type, classified according to the number of plots required for 80% accuracy.*

Number of plots required	Number of areas (frequency)	Cumulative frequency	
		Number of areas	%
35	2	2	8
45	5	7	28
55	8	15	60
65	6	21	84
75	3	24	96
85	1	25	100

Range conditions.—Range conditions on different portions of a type may be classed as poor, average, or good. If these conditions

within a type are sampled independently the number of plots required for each differs from the number required when the plots from all conditions are combined into a single sample.

In Table 4 the results of breaking down three types into three classes based on grazing capacity are shown. The number of plots required to sample the various range condition classes within a given degree of accuracy is less in each instance than the number required for the composite sample. The total number of plots required to sample the type by condition classes, however, is greater than the number required for the type as a single unit. If the number of classes of range conditions were increased beyond three the total number of required plots also would be increased. Under field conditions any attempt to fit sampling intensities to classes of range condition probably would be unwarranted and of doubtful accuracy.

TABLE 4.—*Number of plots necessary for 80% forage factor accuracy for different range conditions within each of three forage types.*

Type	Condition of the range			Total	Composite sample
	Poor	Average	Good		
Dry mountain meadow	34	19	22	75	51
Mountain bunchgrass	12	6	16	34	26
Plains short grass	62	51	40	153	67

Seasonal changes.—Table 5 presents the results of computing the number of plots required to sample a 320-acre short grass subtype with the same degree of accuracy from May to October, inclusive. A series of 50 permanently marked plots were surveyed at the beginning of each month, with the exception of September. Fluctuations in the mean forage factor from month to month are expressions of both climate and forage compositions. The marked rise in forage value for June is due mainly to rapid growth of blue grama and to the appearance of weeds of low palatability. In July and August, growth practically ceased and a considerable portion of the vegetation, which became dry and brown, disintegrated and was lost as forage. September rains, resulting in regrowth, probably account for the increase in forage available in October. Clipping studies and dry forage weight determinations made ndependently of this study show similar

TABLE 5.—*Seasonal change in sampling intensity on a plains short grass subtype in eastern Colorado in 1938.*

Month	Mean forage factor	Standard deviation	Number of plots (80% accuracy)
May	5.180	±2.269	20
June	10.592	±5.151	25
July	6.969	±2.796	17
August	4.634	±1.448	11
October	6.741	±2.844	19

trends and hence indicate that the fluctuations shown in Table 5 are real and not the result of a change in density base on the part of the observers.

Yearly changes.—Table 6 shows the variation in sampling intensity over a period of 3 years for a short grass subtype similar to the one discussed above. These computations are based on a series of 40 permanent plots which were surveyed in September of each year. Forage value was low in 1936, reflecting the effects of drought extending from 1934. Extremely favorable rainfall in 1938 resulted in an excellent forage crop in that year. Much of the variability between years in this example is the result of density changes and changes in relative floristic composition with their accompanying palatability changes. Data similar to those shown in Table 6 are not available for other forage types, but general observation indicates that analogous changes may be expected in other types and other localities.

TABLE 6.—*Yearly change in sampling intensity on a plains short grass subtype in eastern Colorado.*

Year	Mean forage factor	Standard deviation	Number of plots (80% accuracy)
1936	3.012	±0.559	4
1937	3.216	±1.137	14
1938	8.086	±3.549	20

APPLICATIONS

In view of the results presented in preceding paragraphs it is apparent that an arbitrary number of plots cannot be proposed as a means of securing adequate sampling of all types with uniform accuracy on all range units covered by a survey. The purpose of the survey and the nature of the vegetation dictate the basis for establishing the number of plots necessary to sample various types. For example, the use of samples derived from broad types is justified when averages of grazing capacity are needed by such agencies as the Agricultural Adjustment Administration for state and regional planning; a different type of sample is needed when grazing capacities of ranches are required; and lastly, in detailed surveys from which management plans are to be prepared, the adequacy of the sample on individual transects must be considered.

A preliminary sample from which the number of plots needed for a survey of a given accuracy may be calculated by means of standard statistical formulae appears to be more logical than any attempt to establish the required number of plots on a purely arbitrary basis. If a preliminary survey is not feasible, data collected during the course of the survey itself may be analyzed to determine the adequacy of the number of plots being secured. In view of seasonal fluctuations that may be encountered in the survey, samples for preliminary analysis may be taken periodically to provide a basis for adjustment in intensity with season. New samples should also be analyzed as new types are encountered.

In all procedures used for establishing plot numbers, good judgment will be required. For example, a 3,000-acre ranch may have the following statistics:

Forage type	Acres	Forage factor	Forage acres	Percentage of grazing capacity
Grassland	2,100	0.03515	73.815	76.55
Annuals	300	0.00250	0.750	0.78
Sagebrush	450	0.00640	2.880	2.99
Meadow	150	0.12650	18.975	19.68
	3,000		96.420	100.00

In this example, grassland and meadow types should be sampled more adequately than the sagebrush type. A 50% error in sampling the sagebrush type would result in less than 1.5% error in the total grazing capacity of the ranch. A statistically adequate sample of the annual type would be a waste of time and money.

When portions of a large type or management unit are surveyed by sections or other legal subdivisions, more plots than necessary may result from repetition of plot transects. In such cases, fewer plots may be established without impairing sampling accuracy and the time thus saved may be allotted to important grazing types of small area or of infrequent occurrence, in order to obtain more accurate estimates. Careful judgment in certain instances should even make possible the allocation of plots saved from large management units to small management units in key locations. The use of aerial photographs from which types and their acreages can be determined before plots are taken should facilitate this process.

SUMMARY AND CONCLUSIONS

A study of sampling intensity as it applies to the use of the square-foot density method in range surveys was made with sample plot data recorded from range surveys on all of the major range vegetation types in Colorado, Wyoming, and the Black Hills region of South Dakota.

The law of diminishing returns applies to accuracy of surveys by the plot method. Sampling error is proportional to the square root of the number of plots taken.

Different vegetation types require different numbers of plots to secure a given degree of sampling accuracy.

Little relationship exists between the area of a vegetation type and the number of plots necessary to sample it with a given degree of accuracy.

Different portions of a type generally require different numbers of plots for a given degree of accuracy.

Subdividing types on the basis of range conditions and sampling these conditions independently requires fewer plots for each condition class than are required to sample a broad area of the type to the same degree of accuracy. The total number of plots required for all con-

dition classes, however, is greater than the number required for a composite sample of the same area.

Seasonal and yearly fluctuations in floristic composition result in seasonal and yearly fluctuations in the sampling intensity necessary to survey the same area with a given degree of accuracy.

Either a preliminary survey or samples taken periodically from the survey data appear to provide a satisfactory basis for determining the intensity of sampling required in different types.

Plots can be saved by less intensive sampling of large grazing units or vegetation types and by less intensive sampling of types of low grazing capacity. Plots saved can be allotted to small grazing units and small areas of important vegetation types.

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HEAT RESISTANCE IN OAT VARIETIES[1]

Franklin A. Coffman[2]

OATS are generally considered to be less tolerant to heat than any of the leading cereal crops. Despite this situation, the major oat-producing areas of the United States frequently experience high temperatures during the most critical periods of the growth of the crop, and decreased yields of oats resulting from heat and attendant drought are very common. Consequently, any information helpful in preventing or reducing such losses is of interest to oat breeders, farmers, and others.

Statements, presumably based upon observation or deduction, frequently have been published to the effect that red oats, i.e., varieties belonging to *Avena byzantina*, supposedly derivative from the wild *A. sterilis*, are more heat resistant than are the common oat varieties of *A. sativa*, which supposedly are derived from *A. fatua*. Red oats are more widely grown in southern United States and in California, and the warmer sections of the world where oats are produced. Published data on the comparative heat resistance of oat varieties have not been presented, however. Laboratory tests of the heat resistance of oat plants were begun in 1936 in order to obtain some information on this subject. The experiments were limited to young plants, and the results reported here on the relative heat resistance of individual varieties should be considered merely as preliminary indications.

MATERIALS AND METHODS

Much time was consumed in devising a technic which would indicate differences between varieties in heat resistance. The equipment available was a Freas electrically-operated, thermostatically-controlled oven used primarily for the drying of plant materials. The heat in this oven is produced by a current of air passing over electrically-heated coils. The warm air is forced through the oven by a motor-driven fan. The oven temperature was maintained within a range of 2½° to 3° C.

Originally the minimum temperature possible in the oven was about 60° C. Tests indicated this temperature was too severe for oat plants even when the period of exposure was as short as 45 minutes. After some adjustments, however, it was possible to obtain a temperature control ranging from some 48½° to 52° C, which was used in most of the tests.

Two asbestos baffle plates were inserted in the oven, one on the windward side and one at the top to deflect the direct hot-air blast from the plants.[3] The current of hot air was still sufficient to keep the leaves of the oat plants almost constantly in motion.

The pots containing the oat plants were set in a pan containing about 2 inches of water in order to retard drying. This tended to reduce the heat from the bottom

[1]Contribution from the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture. Received for publication July 13, 1939.

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[3]The writer is indebted to C. H. Kyle, senior agronomist, Division of Cereal Crops and Diseases, for assistance in the technic used for testing plants to heat.

of the oven and was helpful in cooling the pots and soil. The water was replenished as it evaporated.

In all the tests on which data are presented, only two pots were placed in the oven at a time. The area of the oven, after the asbestos plates had been inserted, was approximately 16 inches wide, 12 inches high, and 17 inches deep. After one-half the exposure period had elapsed, the position of the pots in the oven was reversed and each pot was then turned so that all of the plants might have, as nearly as possible, the same exposure to the heated air.

Various arrangements of planting the seed in the pots were tried during the course of the experiments. In 1936–37, about six plants were grown per pot. In the test conducted in 1937–38, 6-inch pots were used and two kernels of each of 10 varieties were sown per pot. In all tests in 1938–39, 5-inch pots were used for growing the plants. In one test, two seeds of each of six varieties were sown in a pot, and in another test, four kernels of each of two varieties were alternated. In the most recent tests, five kernels of each of two varieties were planted alternately in a pot.

Preliminary experiments indicated that Fulghum (C. I. 708)[4] was much superior to any of the other varieties tested for heat resistance, and this variety was used as a check in all later tests. Where two varieties were sown alternately in a pot, Fulghum was one of the varieties, and the survival of each variety was calculated in percentage of the check.

DATA OBTAINED

In 1936–37, oat plants in 10 pots were tested for heat resistance at a temperature of some 59° to 60° C. with exposures of 3 to 4 hours. These tests were so severe that only one plant of the Fulghum (C.I. 708) variety survived.

A second series of tests was made in 1937–38 at a temperature range of 48½° to 50° C. Exposure periods ranged from 45 minutes to 4 hours as follows: Two pots for 4 hours, six for 3 hours, four for 2 hours, four for 1 hour, and four for 45 minutes. Two seeds each of 10 varieties were planted in each of 20 6-inch pots so that all varieties presumably had equal exposures. The results indicated that the exposures were still much too severe for oats, but gave further evidence that Fulghum (C.I. 708) was more heat resistant than any of the other varieties then tested. Among the 10 varieties tested, 5 are classed as belonging to *Avena byzantina*, 4 to *A. sativa*, and 1 to *A. sativa orientalis*. The varieties of the latter two groups were alternated with those of *A. byzantina* varieties in seeding. Most of the plants in all pots succumbed but a few survived, usually in pots exposed for the shortest period. The percentage of survival of the different varieties was as follows: Fulghum (C.I. 708), 30.8; Ferguson 71 (Red Rustproof) (C.I. 1039), 10.0; Storm King (C.I. 1602), 8.1; and Coastblack (C.I. 1025), 8.0. The remaining varieties, Markton (C.I. 2053), Brunker (C.I. 2054), Richland (C.I. 787), Victory (C.I. 1145), Cornellian (C.I. 1842), and Red Algerian (C.I. 840), did not survive. In these tests, it seemed that the varieties of *A. sativa* were less heat resistant than those of *A. byzantina*, but this

[4]C. I. refers to accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.

generalization was not confirmed in later tests when additional varieties were tested.

Three experiments were conducted in 1938–39. In the first experiment, two seeds of each of six varieties were sown in each of 35 pots. Thus 69 or 70 plants of each variety were tested. The plants were exposed as follows: 12 pots for 2 hours, 9 pots for 1½ hours, and 12 pots for 1 hour, at a temperature range of 48½° to 52° C. The survival of Fulghum (C.I. 708) was 7.1% after a 2-hour exposure, 11.1% after 1½ hours, and 43.5% after 1 hour. The average survival was 20.3%. No plants of Richland (C.I. 787) survived in any test. In relative survival, calculated on the basis of the survival of the Fulghum check considered as 100%, Victory survived 6.9%, Markton 21.2%, Brunker 28.6%, and Ferguson 71.35%. Fulghum, alone, survived when the exposure was longer than 1 hour. The superiority of Fulghum was notable.

In the second experiment, the same six varieties were sown in 50 pots. Four seeds of Fulghum were sown in each pot alternating with four seeds of one of the other five varieties. Thus, each of the five other varieties was compared with Fulghum in 10 pots. Periods of exposure to heat were one pot for 2 hours, one for 1½ hours, six for 1 hour, and two for 45 minutes at a temperature range of 48½° to 52° C. The data obtained are presented in Table 1. For some reason the Fulghum plants in the pots exposed for 2 hours, all of which were exposed on the same day, survived much better than when exposed for shorter periods. One plant of Ferguson 71 also survived at that exposure. The reason for this is not known. Possibly the oven was not

TABLE 1.—*Survival of five oat varieties compared with Fulghum (C. I. 708), after different periods of exposure to a temperature of 48½° to 52° C.*

Variety	C. I. No.	Percentage survival after exposure for				Average all tests (40 plants)	Percentage of check
		2 hours (4 plants)	1½ hours (4 plants)	1 hour (24 plants)	45 minutes (8 plants)		
Victory	1145	0	0	4.2	121.5	5.0	16.4
Fulghum	708	0	50.0	12.5	100.0	30.5	—
Markton	2053	0	0	4.2	50.0	12.5	25.0
Fulghum	708	75.0	0	37.5	100.0	50.0	—
Brunker	2054	0	0	4.2	28.6*	7.7	14.0
Fulghum	708	0	0	41.7	100.0	55.0	—
Richland	787	0	0	0	0	0	0
Fulghum	708	100.0	0	29.2	88.8	45.0	—
Ferguson 71 (Red Rustproof)	1039	33.3*	0*	17.4*	37.5	21.6	72.0
Fulghum	708	25.0	0	29.2	50.0	30.0	—
Average for Fulghum	......	40.0	10.5	30.0	87.5	42.7	100.0

*One less plant.

functioning normally and the fact was not detected, or else some environmental condition influenced the heat resistance of Fulghum and Ferguson 71 oats that day. With the exception of data for that one day, these tests usually have resulted in progressive increases in survival as the period of exposure to heat was shortened. No plants of any of the other varieties survived when exposed for longer than one hour.

An average of 42.7% of the plants of Fulghum survived in this experiment (Table 1). Considering the survival of Fulghum as 100, the other varieties survived as follows: Ferguson 71 (Red Rustproof), 72%; Markton, 25%; Victory, 16.4%; Brunker, 14%; and Richland, none. It is difficult to explain why Richland failed to survive in these tests. In later tests in which the period of exposure to heat was reduced, Richland showed some tolerance to heat.

In the third experiment in 1938–39, 10 pots each of 23 varieties were sown along with the Fulghum check in each pot. Eight pots of one additional variety were grown in a similar manner. Five seeds of a variety were sown in a pot in alternation with five seeds of Fulghum. The seedlings were made at 1-week intervals, two pots of each variety pair on each date. All pots were exposed in the oven for 45 minutes at the heat range of 48½° to 52° C. Except in the final series of plantings, all the plants were in the five-leaf stage of development when exposed to heat. Due to an oversight the plants in the fifth or final replicate were exposed to the stimulating influence of an artificial light throughout the nights. Although located some distance away, the light caused some variation in the stage of development of these plants. The data obtained, however, do not indicate that the heat resistance of the plants was greatly influenced by the light.

A wide range of varieties was included in this test. About half of the varieties are classed morphologically as belonging to *Avena byzantina* and half to *A. sativa*. The White Russian (White Tartar) variety of *A. sativa orientalis* was included. Midseason, early-maturing, and one late-maturing variety were tested along with the leading varieties of winter oats. Fulghum and Appler (Red Rustproof) oats, shown to be resistant to heat, usually are grown from fall, winter, or early spring seeding and are known to require some cool temperatures in early stages for normal growth and development. They also have considerable cold resistance. It seemed desirable, therefore, to include other varieties of winter oats in the heat experiments.[5] The comparative cold resistance of certain of the winter oat varieties is shown in Table 2. Varieties highly resistant to stem rust, crown rust, and smut were tested. Oat varieties having no dormancy and those having differing degrees of dormancy in freshly harvested seed were included. Black, gray, red, yellow, and white oats; awnless and awned varieties; varieties with and without basal scars; and varieties with and without pubescence were tested.

[5]The writer is indebted to S. C. Salmon, principal agronomist, Division of Cereal Crops and Diseases, for suggesting that heat resistance of winter oats as well as spring oats be investigated.

TABLE 2.—*Comparative survival of 25 varieties of oats after 45 minutes in an oven at 48½° to 52° C.*

Variety	C.I. No.	Plants survived		Percentage of Fulghum, C.I. 708, check as 100	
		Variety named, %	Comparable Fulghum, %	Heat test, %	Hardiness test*, %
Early Maturing, Spring					
Brunker	2054	6.1	30.0	20.3	—
Black Mesdag	1877	20.4	57.1	35.7	—
Columbia	2820	18.0	32.0	56.2	—
Early Joanette†	1092	5.1	12.5	40.8	—
Richland	787	16.0	29.2	54.8	—
Victoria × Richland	3500	6.4	25.0	25.6	—
Average		12.0	31.0	38.9	
Midseason, Spring					
Bond	2733	20.4	43.8	46.6	63.8
Joanette	1880	26.0	50.0	52.0	—
Markton	2053	14.3	46.9	30.5	—
Rainbow	2345	12.5	31.3	39.9	—
Victoria	2401	22.4	52.1	43.0	46.8
Victory	1145	14.0	38.0	36.8	—
Average		18.3	42.7	41.5	55.3
Late, Spring					
White Russian (White Tartar)	1614	4.1	24.5	16.7	—
Average		4.1	24.5	16.7	
Intermediate, Spring-Winter					
Appler	1815	56.0	70.0	80.5	105.8
Fulghum	708‡	40.8	40.8	100.0	100.0
Navarro	966	53.1	52.1	101.9	—
Ruakura	2025	59.2	40.0	148.0	—
Average		51.8	50.6	107.5	102.9
Winter					
Bicknell	3218	44.9	36.0	124.7	117.6
Culred	3217	36.0	30.0	120.0	108.6
Fulghum	2499	66.0	66.7	99.0	113.7
Fulwin	3168	66.0	52.1	126.7	106.3
Hairy Culberson	2505	68.0	55.1	123.4	118.7
Lee	2042	34.7	34.7	100.0	111.0
Tech	947	61.2	58.0	105.5	109.2
Winter Turf	3296	67.3	60.0	112.2	111.0
Average		56.0	49.1	113.9	112.0

*Data from extensive cooperative uniform hardiness nursery tests conducted at several experiment stations.
†Only eight pots were tested, whereas 10 were tested of all other varieties.
‡Average of all pots.

From the results shown in Table 2, it would seem that the only characters specifically associated with heat resistance were those of partial to complete winter growth habit and cold resistance. It was surprising that varieties belonging to *Avena byzantina* were not, on the whole, more heat resistant than are those of *A. sativa*. Only those having some cold resistance or being more or less of the winter type, and adapted to the South, were notably heat resistant.

DISCUSSION

The data obtained indicate that varieties which are more or less winter resistant are apt to be heat resistant as well. It was rather surprising that red oats were not more heat resistant than many varieties of so-called common oats. Possibly, if the plants had been subjected to some sort of hardening, different results would have been obtained. It also is not known how nearly the laboratory set-up approached natural or field conditions. Evidently, from the results obtained heat resistance is not related to any of the characters making for resistance to the major diseases of oats.

The factors responsible for heat resistance in oats would appear to be similar to those that are generally considered to enable plants to resist cold. Either extreme heat or heavy freezing causes a withdrawal of water from plant cells. The close association between heat resistance and cold resistance in oats would suggest that hydrophyllic colloids which retain water in the protoplasm with a considerable inhibitional force are abundant in the resistant varieties.

The fact that heat resistance seems closely related to winter resistance is of interest to plant breeders. If future tests show that heat resistance is a reliable index of winter resistance, the testing of hybrid populations for cold resistance will be greatly simplified. Heat tests can be made in ovens which are more commonly available and less expensive than refrigeration equipment.

The possibilities of breeding for heat resistance in oats would seem to be favorable. Although most of the typical spring oats seem to lack heat resistance, the varieties appear to vary somewhat. Fulghum oats sown in early spring mature normally, and this variety has a marked ability to resist heat. Ruakura, which also matures normally when spring sown, would seem by these tests to have unusual heat resistance. It would seem possible to obtain spring-like oats with more heat resistance than are our present leading spring oat varieties. It is not difficult to conceive of seasons in which heat resistance would be as important a character to an oat variety as is rust resistance in a season when rust is prevalent.

SUMMARY

Oat varieties were subjected to different temperatures for various lengths of time. It was determined that a temperature of 48½° to 52° C for a period of 45 minutes would give results indicating differences in heat resistance of oat varieties. The plants tested were in the five-leaf stage. Experiments were conducted on more than 25 varieties. It was found that varieties differ widely in their ability to

resist heat. Varieties adapted to the South and that are resistant to cold and have at least a partial or intermediate winter growth habit showed the greatest resistance to heat.

Red oats (*Avena byzantina*) as a group were not more heat resistant than many varieties of *A. sativa*. Some varieties belonging to both species were heat resistant. Heat resistance apparently is not correlated with time of maturity, with resistance to any of the major oat diseases, with after-harvest dormancy, or with any of the observed morphological characters of the oat kernel.

GRASSHOPPER INJURY IN RELATION TO STEM RUST IN SPRING WHEAT VARIETIES[1]

RALPH W. SMITH[2]

DIFFERENTIAL injury to cereal crops and varieties by insects is a rather common observation. As a result of insect ravages in recent years, there is an increasing interest in growing field crops resistant to insect injury and also in developing strains less subject to attack by insect pests.

Gilbertson (3)[3] and Dunham (2) report that certain wheat varieties are injured more than others by stem maggot. McColloch and Salmon (6) and Painter, Salmon, and Parker (7) found that certain varieties of winter wheat are more resistant than others to injury by Hessian fly.

Brunson and Painter (1) state that grasshoppers injured corn more than sorghum and that in both crops some varieties were injured more than others. Hume (5) states that dent corn was injured more by grasshoppers than flint corn. Hermann and Eslick (4) observed differential injury caused by grasshoppers in different genera and species and in selections within species in grasses at the Washington Agricultural Experiment Station.

General observation of grasshopper damage to cereal crops in the Dickinson, North Dakota, vicinity in recent years would indicate that these crops, in extent of grasshopper injury, rank in descending order as follows: Barley, oats, wheat, corn, and sorghum. During the grasshopper invasion of 1938, which was the worst ever known at the Dickinson substation of the North Dakota Agricultural Experiment Station, estimates were made of the percentage injury from grasshoppers in field plats of spring wheat, oats, and barley. Averages of the four replications of each variety gave the results shown in Table 1.

TABLE 1.—*Average percentages of heads cut off by grasshoppers in field plats of spring wheat, oats, and barley at Dickinson, N. Dak., 1938.*

No. of varieties	Crop	Heads wholly or partly cut off, %
24	Spring wheat	38
16	Oats	51
15	Barley	57

In 1938 there also occurred a very destructive epidemic of stem rust in the vicinity of Dickinson. This gave an unusual opportunity to study the correlation between grasshopper injury and percentage of stem rust in spring wheat varieties. The percentage of heads lost through grasshopper injury and the percentage of stem rust were estimated for all varieties in the general spring wheat nursery.

[1]Contribution from the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, in cooperation with the North Dakota Agricultural Experiment Station. Received for publication July 17, 1939.

[2]Associate Agronomist, Division of Cereal Crops and Diseases.

[3]Reference by number is to "Literature Cited", p. 820.

It was observed that, with a few exceptions, rust-resistant varieties showed limited grasshopper injury, while severely rusted varieties, in general, were badly injured by the insects. Correlation coefficients calculated for different sections of the nursery are shown in Table 2. These rather high correlations show a decided tendency for grasshopper injury to increase with an increase in rust prevalence. The varieties in groups 1 and 2 were consecutive, while in group 3 all varieties having only a trace of rust were omitted.

TABLE 2.—*Correlations between percentage of heads cut off by grasshoppers and percentage of stem rust in varieties of spring wheat at Dickinson, N. Dak., 1938.*

Group	No. of varieties	Heads cut off, %			Stem rust, %			Correlation between grasshopper injury and stem rust
		Max.	Min.	Av.	Max.	Min.	Av.	
1	100	95	10	51.7	75	0	39.4	$r = +0.767 \pm 0.028$
2	225	100	10	42.9	75	0	17.1	$r = +0.512 \pm 0.033$
3	256	100	10	51.5	75	0	36.7	$r = +0.787 \pm 0.016$

The varieties or strains of wheat studied were mostly unnamed hybrid selections. A few named varieties were included and the data recorded in Table 3 show, in general, a decrease in grasshopper injury as the percentage of rust decreases. A marked exception is Hard Federation in which the strong peduncle evidently enables it to resist hopper injury despite its high susceptibility to rust.

TABLE 3.—*Estimated percentage of heads cut off by grasshoppers and percentage of stem rust in 14 varieties of spring wheat at Dickinson, N. Dak., 1938.*

Variety	Heads cut off, %	Stem rust, %
Reward	95	75
Reliance	93	75
Red Fife	90	75
Haynes	85	70
Marquis	80	75
Ceres	72	73
Supreme	60	75
Kota	60	60
Komar	58	73
H-44	35	15
Thatcher	31	6
Hope	20	2
Pilot	20	2
Hard Federation	15	75

Several theories have been advanced to explain why badly rusted varieties are injured more by grasshoppers than rust-resistant varieties, but the writer is unable to state which of the following factors are important: (a) It has been suggested that a changed chemical content of the rusted stems, such as a greater sugar percentage, makes them preferred by the insects; (b) another theory is that the high protein content of the rust spores (18% in one sample) makes them

attractive to the hoppers; (c) some varieties have stems that are softer or more juicy, and hence are more attractive to the insects; (d) perhaps the fact that wheat stems punctured by rust pustules are more easily broken over and chewed off than are normal stems accounts for much of the difference.

The writer has no evidence to indicate that rust-resistant varieties are less palatable to grasshoppers than susceptible varieties when rust is not present; also, evidence is lacking with which to determine to what extent the insects prefer rusted to rust-free grain, or whether the difference lies mainly in greater ease of destruction of the former.

The stage of maturity of the plants seems to have considerable influence on the amount of injury but cannot account for all of the differences noted as both early and late varieties are found in both the badly injured and slightly injured groups.

The greater number of the grasshoppers present in 1938 were identified by entomologists as the lesser migratory species, *Melanoplus mexicanus* (Sauss.). Locally hatched hoppers that survived poisoning were augmented by swarms that blew in with warm south winds, especially on July 10.

After the middle of July the number of grasshoppers was gradually reduced, apparently due to migration with the wind to the north or northwest. Enough remained, however, to lay sufficient eggs to menace the crop of 1939.

SUMMARY

The leading cereal crops at Dickinson, N. Dak., in the extent of grasshopper injury, ranked in descending order as follows: Barley, oats, wheat, corn, and sorghum.

Certain spring wheat varieties were injured by the grasshoppers more than others.

With some exceptions, badly rusted wheat varieties were injured considerably more than those showing but little rust. In three different groups of spring wheat in the nursery the correlation coefficients between percentage of stem rust and percentage of grasshopper injury were $r = +0.512 \pm .033$, $+0.767 \pm .028$, and $+0.787 \pm .016$.

Several unconfirmed reasons are suggested for the greater damage to rusted varieties.

The stage of maturity of a variety seems important but apparently cannot account for all the differences since both early and late varieties were found in both the badly injured and slightly injured groups.

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NOTE

HARVESTING BUFFALO GRASS SEED FOR INDIVIDUAL USE

BUFFALO grass seed was successfully harvested at the Blackland Experiment Station at Temple, Texas, this season during the last week in June, at the rate of about 1 pound per man hour cleaned unhulled weight. A lawn mower was prepared for the job by removing the cutter bar, taking off the roller, attaching an ordinary grass catcher, and placing a shield on top of the mower and up the handle to deflect the scattering seed into the catcher (Fig. 1).

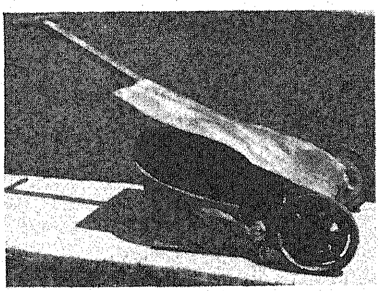

FIG. 1.—An ordinary lawn mower reconstructed to harvest buffalo grass seed.

This machine was used on a buffalo grass lawn that had been mowed regularly and on a field area that had been cut with a mowing machine immediately prior to the seed collecting operation. In both cases satisfactory amounts of seed were secured. On the lawn, earthworms had worked up considerable soil which was caught with the buffalo grass seed. This soil was removed by placing the catch in a tub of water and skimming the seed from the top.

By using this method of collecting seed, the amount of hay that is caught in addition to the seed is materially reduced by removing the cutter bar on the lawn mower. The separating process is thus simplified so that the coarser surplus hay is easily removed by hand. Fanning is then effective in the removal of the smaller trash particles. Neither the floating nor the fanning need be done if the seed are to be planted by the collector.

This economical method of harvesting buffalo grass seed will make possible the seeding of pastures to this grass, an operation that has not been practicable because of the difficulty in securing a seed supply.—H. O. HILL, *Texas Blackland Experiment Station, Temple, Texas.*

AGRONOMIC AFFAIRS

NO CHANGE IN DATE OF ANNUAL MEETINGS

REGARDLESS of the dates established nationally or locally for the celebration of Thanksgiving Day, the announced dates for the annual meetings of the American Society of Agronomy and of the Soil Science Society of America will remain unchanged. The two societies will meet at the Hotel Roosevelt in New Orleans November 22, 23, and 24, according to official confirmation by the executive committee.

VOLUME I OF PROCEEDINGS REPRINTED

VOLUME I of the PROCEEDINGS of the Soil Science Society of America has been reprinted and can now be obtained from the Treasurer of the Society, Dr. G. G. Pohlman, Agricultural Experiment Station, Morgantown, West Virginia, for $5.00 post paid. The volume contains the papers presented at the 1936 meeting, together with the transactions of the business meeting of the Society for that year, the constitution and by-laws, and other items pertaining to the organization of the Society and the establishment of the PROCEEDINGS.

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"SLICK SPOTS" IN NEBRASKA[1]

J. W. Fitts, H. F. Rhoades, and E. S. Lyons[2]

IN the Platte and North Platte valleys of Nebraska there are many small areas that will support little or no crop growth. These areas are commonly known as "slick spots" because of their slick, greasy feel when wet. Similar areas have been described by Peterson (10),[3] Isaak (8), Catlin and Vinson (3), Burgess (2), Gardner, Whitney, and Kezer (5), and others.

The slick spots described by these investigators have a puddled structure and are quite impervious to water. It is generally considered that their poor physical condition is due to the presence of sodium ions in the exchange complex of the soil. Peterson (10) found that slick spots in Idaho were considerably higher in carbonate than the normal soils and suggested that the impervious nature of the slick spots was due to the cementing action of calcium carbonate. Isaak (8) noted a higher content of clay in the slick spots.

The slick spots mentioned in this paper are found on the first-bottom lands, particularly in association with Minatare, Laurel, and Lamoure soils, but occasionally they occur on low bench land mapped as Tripp. They vary from a few square feet to several acres in extent and are heterogeneously scattered throughout the fields. Such areas are expensive to the irrigation farmer, especially when the land is in sugar beets. They are so irregular in shape and, in many cases, so small, that they usually cannot be left out of the field. Accordingly, they add to labor costs, often as much as $25.00 an acre of "spots", without contributing any return. Practical experience has amply proved that they cannot be improved by the ordinary practices of culture or fertilization.

Slick spots vary in their adaptability for plant growth. If the climatic conditions are favorable when alfalfa is planted, a good stand may be obtained except on the most severe slick spots. However, after

[1]Contribution from the Department of Agronomy, Nebraska Agricultural Experiment Station, Lincoln, Nebr. Published with the approval of the director as paper No. 227 Journal Series. Received for publication May 24, 1939.

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The authors wish to express their appreciation for the suggestions and criticisms offered by Prof. J. C. Russel.

[3]Figures in parenthesis refer to "Literature Cited", p. 831.

a few months the alfalfa dies. Under less severe conditions some of the alfalfa may survive. Sorghums and small grains appear to be even more sensitive. Occasionally, sugar beets will grow even in the more severe areas. However, the stand is not uniform and usually the yield is low.

PLAN OF THE INVESTIGATION

Laboratory and field studies are in progress at the Nebraska Agricultural Experiment Station to ascertain the physical and chemical nature of slick spots and to find methods suitable for their reclamation and management. It is the purpose of this paper to report data on mechanical analysis, carbonates, pH, exchange capacity, exchangeable calcium, magnesium, sodium, and potassium, and percentage saturation with sodium and potassium of slick spots and normal soils from four fields. The soil samples used in this study were taken from the following fields.

Field 1.—This field is located in the North Platte Valley, near Minatare, Nebraska. It is mapped as Minatare silt loam (13). The slick spots are numerous and conspicuous. The normal soil is of only medium productivity. The water table occurs at 3 or 4 feet below the surface. This soil is very calcareous. The impervious layers of the slick spot apparently occur at a depth between 10 and 16 inches.

Field 2.—This field is located in the Platte Valley near Lexington, Nebraska. It is mapped as Lamoure very fine sandy loam (6). The slick spots are abundant and conspicuous by their slightly higher elevation and lighter color throughout the profile. The normal soil in the areas sampled is of relatively low productivity, although it is distinctly better than the slick spots. The water level occurs about 6 feet below the surface. This soil is non-calcareous generally above 30 to 36 inches, but in slick spots it is calcareous at a shallower depth. The impervious layer appears to occur between 6 and 9 inches, but the soil below is distinctly impervious also.

Field 3.—This field is located in the North Platte Valley near Scottsbluff, Nebraska. It is mapped as Tripp fine sandy loam (13). Slick spots, varying in severity, are scattered throughout the field. The water level occurs about 6 feet below the surface. The soil is only slightly calcareous in the surface but has relatively large amounts of lime in the lower depth. Slick spots have more lime in layers close to the surface than the normal areas. The slick spot sampled in this field was unique in the abruptness in which the impervious layer occurred. The upper 8 inches had a fair structure, but immediately below there was a very impervious sticky plastic layer.

Field 4.—This field is located in the North Platte Valley near Bridgeport. It is mapped as Laurel very fine sandy loam (7). The slick spots are conspicuous because of their slightly higher elevation and lighter color. The water level occurs about 5 feet below the surface. This soil is calcareous in both normal and slick spot areas. The impervious layer occurs at 7 inches and is distinctly impervious to a depth of 29 inches. The normal soil is of average productivity.

SOIL SAMPLING

The slick spots in Nebraska vary a great deal in their profile characteristics and their adaptability for crop growth. They vary greatly within the same field and even in a given slick spot. The impervious layers do not always occur at the same depth. If the impervious layer occurs at or near the surface an unfavorable

condition results. The depth below the surface and the thickness of the impervious layer determine largely the ability of the slick spot to absorb water and to support crop growth. However, normal soils[4] in those fields containing slick spots are only medium in productivity and may be considered as the "best conditions" found in the field.

Because of the heterogeneity of these spots, it was deemed unwise to take a large number of samples from different spots at given depths and composite them. Instead, trenches were dug in selected slick spots and representative samples were taken for each layer from the face of the pit. A trench was then dug in a normal area as close to the slick spot as possible, and samples were taken from corresponding depths. It was found in almost every case that the depth of the layers in the normal soils was about the same as in the corresponding slick spot.

EXPERIMENTAL

MECHANICAL ANALYSIS

Mechanical analysis was made according to the Robinson pipette method as modified by Engle and Yoder (4). The centrifuge used was of the usual type built by the International Equipment Company for the mechanical analysis of soils. The speed of the centrifuge was 1,200 r.p.m. and the minimum time of centrifuging was 2 minutes. Engle and Yoder did not recommend this procedure for alkali or highly calcareous soils. However, the small amount of soluble salts (0.2% or less) or the large quantity of calcium carbonate present in the soils studied did not seem to interfere with the analysis. The data indicate that practically all of the calcium carbonate was found in the separate less than 0.005 mm.

The above method was slightly modified to determine the carbonate-free particles less than 0.005 mm. A quantity of air-dry soil equivalent to 15 grams of oven-dry soil was placed in a small beaker, moistened with distilled water, and 3 N hydrochloric acid was added a few drops at a time until effervescence ceased. A few more drops of acid and about 100 cc of water were then added and the mixture thoroughly stirred. The quantity of calcium chloride formed by the addition of hydrochloric acid to the highly calcareous soils caused the finer separate to flocculate upon standing. To overcome this, two portions of the separate less than 0.005 mm were determined for each sample. The first determination was made by allowing the soil and water mixture to stand overnight. The clear supernatant liquid was then decanted and the soil washed into a centrifuge tube. After centrifuging 10 or 12 minutes, the clear supernatent liquid was decanted and discarded. This procedure was repeated until a trace of suspension appeared in the supernatent liquid. After that, the supernatent liquid was decanted into a large cylinder and the soil remaining in the tube was deflocculated by adding a few drops of ammonium hydroxide and triturating. With repeated centrifuging the time was reduced to 2 minutes. The supernatent liquid was relatively clear after about 900 cc of suspension had been collected. Distilled water was then added to bring the volume to 1,000 cc. The suspension was thoroughly stirred and a sample was removed immediately for the determination of particles less than 0.005 mm. The procedure of Engle and Yoder was then followed in separat-

[4]The term "normal soil" as used in this paper refers to the parts of the field where plant growth is normal. It is not to be confused with the term as used in soil classification.

ing the remaining soil in the centrifuge tube. The percentages of the two portions of particles less than 0.005 mm were then added to obtain the total carbonate-free separate.

The mechanical analysis data by the method of Engle and Yoder and the percentages of carbonate-free separate less than 0.005 mm are presented in Table 1. The calcium carbonate contents and comparisons with percentages of particles less than 0.005 mm are shown in Table 2. The data of Table 1 show no consistent differences between the slick spots and normal soils. All of the soils were relatively high in the separate greater than 0.05 mm and low in the separate 0.05 to 0.005 mm. Except for field 1, the percentages of particles less than 0.005 mm by the two methods show about the same trends. The percentages of carbonate-free particles less than 0.005 mm in the normal soils were higher than in the slick spots for the three depths of fields 1 and 4 and lower in the three depths of field 3. In field 2, the percentages of particles less than 0.005 mm in the first depth of the normal soil was equal to that of the slick spot, while in the second depth the slick spot was higher and in the third depth the normal soil was higher.

TABLE 1.—*Mechanical analysis of "slick spots" and normal soils from four fields.*

Depth, inches	Mechanical analysis by method of Engle and Yoder, %						Carbonate-free, %	
	>0.05 mm		0.05–0.005 mm		<0.005 mm		<0.005 mm	
	Normal	Slick	Normal	Slick	Normal	Slick	Normal	Slick
				Field 1				
0–3	53.6	50.8	15.0	16.3	31.4	32.9	20.1	17.4
3–10	53.5	48.9	11.4	13.3	35.1	37.8	18.7	17.0
10–16	40.8	24.1	12.4	8.6	46.8	67.3	19.3	14.3
				Field 2				
0–6	53.6	60.6	17.0	10.2	29.4	29.2	28.8	28.6
6–9	51.0	48.7	19.1	8.4	29.9	42.9	29.0	40.0
9–15	34.1	43.5	15.2	12.6	50.7	43.9	49.4	37.2
				Field 3				
0–8	74.5	72.0	9.6	7.9	15.9	20.1	17.3	19.1
8–15	75.6	49.7	10.0	9.6	14.4	40.7	16.3	25.3
15–22	51.9	36.2	14.2	11.2	33.9	52.7	21.5	27.4
				Field 4				
0–7	61.4	73.9	17.3	10.8	21.3	15.3	17.9	14.8
7–13	59.7	71.5	14.2	10.8	26.2	17.7	20.8	14.5
13–19	41.3	64.0	15.4	9.7	43.3	27.3	23.5	17.5

A study of columns 2 and 5 in Table 2 shows that there is no consistent difference between calcium carbonate contents of slick spots and normal soils. In the third depth of fields 1 and 2, the slick spots contained a much greater percentage of calcium carbonate than the normal soils, but there was no difference in the other two depths. In

field 3 the slick spots contained a higher percentage of calcium carbonate in all three depths while the reverse was true for field 4.

TABLE 2.—*Calcium carbonate content, percentage of particles less than 0.005 mm by the Engle and Yoder method, and the sum of the percentages of calcium carbonate and carbonate-free particles less than 0.005 mm for slick spots and normal soils from four fields.*

Depth, inches	Normal soil			Slick spots		
	Calcium carbonate, %	<0.005 mm (Engle & Yoder), %	Carbonate-free particles <0.005 mm + calcium carbonate, %	Calcium carbonate, %	<0.005 mm (Engle & Yoder), %	Carbonate-free particles <0.005 mm + calcium carbonate, %
			Field 1			
0–3....	14.0	31.4	34.1	14.7	32.9	32.1
3–10...	17.6	35.1	36.3	17.8	37.8	34.8
10–16...	27.2	46.8	46.5	45.9	67.3	60.2
			Field 2			
0–6....	0.3	29.4	29.1	0.5	29.2	29.1
6–9....	0.3	29.9	29.3	0.4	42.9	40.4
9–15...	0.3	50.7	49.7	9.6	43.9	46.8
			Field 3			
0–8....	0.9	15.9	18.2	1.8	20.1	20.9
8–15...	1.9	14.4	18.2	11.7	40.7	37.0
15–22...	17.2	33.9	38.7	18.2	52.7	45.6
			Field 4			
0–7....	6.0	21.3	23.9	4.1	15.3	18.9
7–13...	9.7	26.2	30.5	4.9	17.7	19.5
13–19...	18.1	43.3	41.6	12.8	27.3	30.3

The data of columns 3, 4, 6, and 7 in Table 2 show the sum of the percentages of carbonate-free particles less than 0.005 mm to be approximately equal to the percentage of particles less than 0.005 mm as determined by the method of Engle and Yoder. Apparently the carbonate exists in these soils largely in a finely divided state.

EXCHANGEABLE BASES AND BASE EXCHANGE CAPACITY

The procedure used in studying the base exchange characteristics of slick spots was essentially the same as that developed by Magistad and Burgess (9) for calcareous soils, except the several leachings and washings were performed by the method described by Russel (12).

The first leaching to remove soluble salts was made with 500 cc of 50% methyl alcohol. The second leaching to remove the exchangeable bases was made with 500 cc of 0.1 normal barium chloride in 90% methyl alcohol. The third leaching to saturate with ammonium ions for base exchange capacity was made with 250 cc neutral normal ammonium acetate. The excess ammonium salts was removed with 250 cc of 50% methyl alcohol. Excess barium in the leachate was precipitated by 3 N potassium chromate from a warm solution. Calcium was precipitated as the oxalate and determined volumetrically by potassium permanganate

titration. Magnesium was determined gravimetrically as the pyrophosphate. Replaced ammonium was determined by distillation from Kjeldahl flasks, using calcium oxide as the displacing base. Replaceable sodium and potassium[5] were not determined directly but were computed collectively as the difference between the base exchange capacity and the sum of the exchangeable calcium and magnesium. The pH of the soils was determined by the Coleman pH Electrometer.

The data presented in Table 3 show that the slick spots are higher in exchangeable sodium and potassium than their corresponding normal soils. There are, however, variations in the base exchange properties of slick spots and normal soils from the different fields studied. The slick spot of field 1 has a very low content of exchangeable sodium and potassium in the first layer, but the two lower layers are relatively high. In contrast, the slick spots of fields 2, 3, and 4 have a high content of exchangeable sodium and potassium in the three depths studied. The normal soils differ even more. In field 1 the normal soil has no exchangeable sodium and potassium in the surface depth, but it has an appreciable quantity in the lower depth. The normal soil of field 4 has a low content of exchangeable sodium

TABLE 3.—*Exchange capacity, exchangeable calcium, magnesium, and sodium and potassium of slick spots and normal soils from four fields.*

Depth, inches	Exchange capacity, M.E. /100 grams		Exchangeable Ca, M.E./100 grams		Exchangeable Mg, M.E. /100 grams		Exchangeable Na+K (by difference), M.E./100 grams	
	Normal	Slick	Normal	Slick	Normal	Slick	Normal	Slick
				Field 1				
0–3	13.68	13.33	10.27	9.55	3.90	3.57	0.00	0.21
3–10	14.43	15.40	8.83	6.25	3.66	4.32	1.94	4.87
10–16	16.10	14.80	6.70	4.52	4.93	2.29	4.47	7.99
				Field 2				
0–6	17.70	16.60	5.63	4.03	6.55	5.32	5.52	7.25
6–9	16.50	22.30	4.33	3.49	7.10	7.79	5.07	11.02
9–15	31.53	20.92	10.70	4.80	12.75	7.68	8.08	8.44
				Field 3				
0–8	14.67	15.64	7.70	7.29	1.96	1.28	5.01	7.07
8–15	12.35	17.92	5.58	3.99	1.96	0.91	4.81	13.02
15–22	17.12	23.17	9.61	4.19	4.23	1.06	3.28	17.92
				Field 4				
0–7	13.89	13.11	10.14	5.31	1.33	1.57	2.42	6.23
7–13	12.52	11.51	10.37	1.67	1.59	1.06	0.56	8.78
13–19	15.21	13.07	11.14	1.35	2.86	2.14	1.21	9.58

[5]The authors recognize the desirability of methods for the direct determinations of sodium and potassium. However, it has been the experience of the authors that the direct determinations of sodium and potassium displaced by a barium chloride solution are subject to considerable error. On the other hand, satisfactory determinations of calcium and magnesium may be made. Therefore, the computation of sodium and potassium by difference may be expected to be about as accurate as their direct determination.

and potassium in the three depths while fields 2 and 3 are relatively high in the three depths. Field 2 differs from the others in that the soils are higher in exchangeable magnesium than in exchangeable calcium.

Data on the degree of saturation of the exchange complex by sodium and potassium together with pH determinations and calcium carbonate contents are shown in Table 4. There appears to be a fairly close relationship between the pH of the slick spots and normal soils and their respective percentages of exchangeable monovalent ions and calcium carbonate. Minimum pH values of 7.6 to 7.9 occur in the layers of normal soils which contain 6% or less of calcium carbonate and where the degrees of saturation with exchangeable sodium and potassium range between 15 and 35%. Maximum pH values of 9.3 to 9.7 occur in layers of the slick spots which contain 5 to 45% calcium carbonate and where the degrees of saturation with exchangeable sodium and potassium are greater than 50%. In the pH range of 8.0 to 8.4 there are two groups of conditions. The soils in one group contain 10 to 20% calcium carbonate, but the saturation with exchangeable sodium and potassium is less than 20%. The soils of the other group contain less than 4% calcium carbonate, but the saturation with exchangeable sodium and potassium is between 40 and 50%. Four soil layers have pH values between 8.5 and 9.2. Two of these having pH values of 9.0 and 9.1 contain appreciable quantities of calcium carbonate with 28 and 40% saturation with sodium and potassium. According to their contents of calcium carbonate and exchangeable sodium and potassium, the other two soils having pH values of 8.6 and 8.8 would be expected to have pH values of approxi-

TABLE 4.—*Percentage saturation with sodium and potassium, pH, and percentage calcium carbonate of slick spots and normal soils from four fields.*

Depth, inches	Saturation with Na+K, %		pH		Calcium carbonate, %	
	Normal	Slick	Normal	Slick	Normal	Slick
			Field 1			
0–3	0.0	1.6	8.4	8.4	14.0	14.7
3–10	13.4	31.4	8.6	9.1	17.6	17.8
10–16	27.8	54.0	9.0	9.5	27.2	45.9
			Field 2			
0–6	31.2	44.7	7.7	8.4	0.3	0.5
6–9	30.7	49.4	7.9	8.8	0.3	0.4
9–15	25.6	40.3	7.8	9.1	0.3	9.6
			Field 3			
0–8	34.2	45.2	7.7	8.4	0.9	1.8
8–15	38.9	72.7	8.2	9.5	1.9	11.7
15–22	19.2	77.4	8.2	9.3	17.2	18.2
			Field 4			
0–7	17.4	47.5	7.6	8.2	6.0	4.1
7–13	4.5	76.3	8.0	9.4	9.7	4.9
13–19	8.0	73.3	8.3	9.7	18.1	12.8

mately 8.4. However, small discrepancies may be due to a difference in the ratio of sodium to potassium as well as to errors in the pH determinations.

DISCUSSION

Slick spots vary so much in their adaptability for plant growth and in other characteristics that it is difficult to select any one factor as being responsible for their poor condition. The results reported in this paper indicate that the poor physical condition of slick spots is due mainly to the presence of exchangeable sodium and potassium. Observations of physical characteristics and other properties both in the field and laboratory make it logical to assume that sodium is largely responsible. In the field it was noticed that certain layers in slick spots containing large quantities of calcium carbonate and sand were extremely hard and impervious to water. It was found that the clay from these layers was highly saturated with monovalent ions. Apparently the mixture of dispersed clay, calcium carbonate, and sand resulted in the formation of a concrete-like mass. In comparison, those layers that contained clay highly saturated with exchangeable monovalent ions but with low quantities of calcium carbonate did not appear so dense and refractory. Those layers in the normal soil that contained large quantities of calcium carbonate and a high degree of saturation of the clay with calcium and magnesium were not impervious. The influence of calcium carbonate on the physical properties of the soil appears to depend upon the exchangeable ions associated with the clay. Of course the amount of clay present would also affect the physical condition of the soil.

The inability of plants to grow normally in slick spots may be due to the physical nature of the soil and to the high pH. It has been observed many times that plants growing on these spots wilt very soon after an irrigation while the plants growing on the normal soils have sufficient water for optimum growth. The irrigation water does not penetrate the slick spots readily even when the soil is in a loosened condition. The first addition of water puddles and compacts the soil so that water penetration is limited to a few inches. This puddled and compacted soil offers a poor physical medium for the growth of plants because of the low water supply and the poor aeration. In addition the slick spots have such a high pH that plants may be unable to absorb nutrients. Breazeale and McGeorge (1) have shown that plants are unable to absorb phosphate or nitrate ions readily at a pH above 7.6. In the calcareous slick spots phosphorus and iron compounds are relatively insoluble. The lack of available calcium may be serious in non-calcareous slick spots. Ratner (11) suggested that the death of plants in soils high in exchangeable sodium may be due to the breaking down of the calcium regime. Plants would be expected to obtain sufficient calcium in the calcareous slick spots, but some plants may be unable to utilize calcium at a high pH.

SUMMARY

Mechanical analysis, carbonates, pH, exchange capacity, exchangeable calcium, exchangeable magnesium, exchangeable sodium and

potassium, and percentage of saturation with sodium and potassium are reported for slick spots and normal soils from four fields in the North Platte and Platte valleys of Nebraska. The data may be summarized as follows:

1. There was no consistent difference found between the calcium carbonate content of the percentage of particles less than 0.005 mm of slick spots and normal soils. In the mechanical analysis procedure of Engle and Yoder (4) most of the calcium carbonate was analyzed in the separate less than 0.005 mm.

2. The slick spots were consistently higher than the normal soils in percentage of saturation with sodium and potassium. The poor physical properties of the slick spots was attributed to the higher content of exchangeable sodium and potassium.

3. A close relationship is shown between the pH of the slick spots and normal soils and their respective percentages of exchangeable monovalent ions and calcium carbonate.

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A COMPARISON BETWEEN YIELDS CALCULATED FROM THE GRAIN-STRAW RATIO AND THOSE CALCULATED FROM SMALL CUT-OUT AREAS[1]

J. F. DAVIS[2]

IN order to insure a valid interpretation of field plat data the value of correct statistical analysis of the results is practically universally recognized. With the use of statistical methods requiring more replicates the number of field plats is materially increased and the labor involved in the care of these extra plats is correspondingly greater. Therefore, any means that results in a saving of time and which does not lessen the accuracy of the data obtained would be a very desirable addition in field work operations.

In a recent paper,[3] a plan was suggested in which the yields of experimental plats can be accurately determined from the grain-straw ratio.[4] If plat yields determined from the grain-straw ratio are sufficiently reliable, the hand labor involved in cutting out small areas in the plat can be eliminated, thus materially facilitating harvesting operations. This proposed method of plat yield determination would apply primarily to plats with sufficient area so that a binder can be used in harvesting. Plats with an area of 1/30 acre can be harvested in this way. Also, this size of plat is large enough to allow for the discarding of a portion of the crop to eliminate border effects. In order to simulate field conditions and farming practices as closely as possible in carrying out an experiment, a program that allows for that size and shape of plat which makes practical the use of ordinary machinery is very desirable. The relationship of fertilizer placement to growth response of a crop makes it extremely important that results secured from an experiment carried out under one set of conditions are not allowed to refer to similar work carried out under different conditions. For example, in fertilizer studies with small grains it is illogical to assume that fertilizer applied broadcast over a plat is necessarily going to produce the same response as it would if applied with a grain drill with fertilizer attachment, the usual method employed by Michigan farmers. It would appear, then, in this particular case that the plat should be large enough to allow the use of a grain drill. However, this increases the area and requires more labor. Past experience has shown that one of the most important limiting factors in small grain fertilizer experiments is the labor involved at

[1] Contribution from the Soils Section of the Michigan Agricultural Experiment Station, Michigan State College, East Lansing, Mich. A portion of a thesis submitted to the faculty of Michigan State College in partial fulfilment for the degree of master of science. Authorized for publication by the Director as Journal Article No. 352 n.s. of the Michigan Experiment Station. Received for publication July 5, 1939.

[2] Assistant in Soils. The writer is indebted to Professor W. D. Baten for assistance in the preparation of this manuscript.

[3] DAVIS, J. F., and COOK, R. L. A comparison between actual plat yields and those calculated from grain-straw ratios. Proc. Soil Sci. Soc. Amer., 1:265–268. 1937.

[4] The term grain-straw ratio refers to the relationship existing between the grain weight and the weight of the unthreshed bundles.

harvesting time. It is for this type of work that determining plat yields with a minimum of work would prove advantageous in the field work program.

Any method then that reduces the hand labor involved and at the same time is sufficiently accurate to give dependable results, is very desirable. In this paper a comparison between yields calculated by this method and yields secured by the usual method of cutting out small areas from the plat will be made in order to determine which method gives results most comparable to those obtained from threshing the entire plat.

PROCEDURE

The comparisons between the different methods of harvest were made on a series of 16 oat plats. These plats were 14 by 150 feet in size, consisting of 22 rows 7 inches in width, representing one round with an 11-disc grain drill, the type extensively used in the planting of field plats at the Michigan Experiment Station. Six areas, 6 rows by 16½ feet, were cut out of each plat with a hand sickle and each area was labeled to denote the order in which the areas were cut. Since from the appearance of the plats very little difference could be observed in the growth of grain in different portions of an individual plat, the cut-out areas were taken alternately from either side of the plat. This constituted a total area of 6 rows by 99 feet that was cut out of each plat with the hand sickle. The ends of each plat were cut off with the binder, thus leaving approximately 135 feet to be harvested from the original 150 foot plat.

After the cut-out areas were removed and the bundles tied and labeled, the remainder of the plat was cut with the binder. The area cut off the end of each plat allowed for sufficient space for the binder to clean out between any two plats in adjoining blocks. The bundles from each plat were shocked on the plat and when dry were weighed and threshed. During the threshing operations five bundles were selected at random and threshed individually as were the areas cut out with the hand sickle. All the bundles from the plat were then threshed to get the actual yield of each plat. Yields based on one, two, three, four, five, and six cut-out areas were then computed for each plat. In addition, yields for each plat were calculated from the grain-straw ratios and the total bundle weights. This was done for one, two, three, four, and five bundles selected at threshing time.

From the six "cut-out" areas one area was selected at random from each plat and a comparison made between the results thus obtained and those obtained from the systematically selected areas. From the data, correlation coefficients, corresponding "Z" values, the lines of best fit, standard errors of estimate, and the standard errors of estimate from the line $Y = X$ were calculated.

DISCUSSION

CORRELATION COEFFICIENTS

The correlation coefficients obtained in the study are recorded in Table 1. The correlation coefficients represent the relationship between yields calculated by the various methods used in harvesting and the yields secured from threshing the entire plat. The correlation coefficients in each case were found to be significant and ranged from .7500 for the low-yielding cut-out area to .9635 for the comparison

between the actual plat yield and the yield calculated from five threshed bundles.

TABLE 1.—*Correlation coefficients, corresponding Z values, and mean differences of Z values of five bundles threshed and other methods of harvest.*

Methods of harvest	r*	Z	Mean difference
5 bundles threshed	.9635	1.9935	——
4 bundles threshed	.9632	1.9894	.0041±.3922
3 bundles threshed	.9456	1.7857	.2078±.3922
2 bundles threshed	.9203	1.5910	.4025±.3922
1 bundle threshed	.9018	1.4819	.5116±.3922
6 areas threshed	.8462	1.2429	.7506±.3922
5 areas threshed	.8487	1.2516	.7419±.3922
4 areas threshed	.8336	1.2000	.7935±.3922
3 areas threshed	.8773	1.3642	.6293±.3922
2 areas threshed	.7819	1.0503	.9432±.3922
1 area threshed	.7500	.9730	1.0205±.3922

*The 5% point =.6226.

By examining Fisher's Table V.A. (page 212),[5] it is found that all the correlation coefficients are significant. It can readily be noted that the correlation coefficients for the one-, two-, three-, four-, and five-bundle comparisons were considerably higher than any of the coefficients from the cut-out area comparisons. The inference, then, is that yields obtained from weight relationships more nearly approach the actual plat yields than do yields based on area relationships. However, due to the small number of comparisons available, the "r" values were changed to "Z" values in order that a more nearly correct evaluation of the data could be made.

VALUE OF Z

The magnitudes of the Z values bring out more clearly the differences existing between the various methods of harvest. However, the only significant differences in the "Z" values are in the comparisons between one and two cut-out areas and the five bundles selected at harvest time. The difference between the "Z" value for the four cut-out areas and that from the five bundles closely approaches significance. It should be mentioned here that the standard error of a "Z" value is calculated as the reciprocal of the square root of a number three less than the number of items. It can easily be seen, then, that with a "Z" value calculated from data in which the number of items is necessarily limited the corresponding standard error is relatively large as compared to a similar "Z" value obtained from a large number of items. In previous work,[6] it was found that "Z" values obtained from similar data but with more replicates showed significant differences. It seems logical to assume that significant differences would actually exist between yields based on five and six cut-out areas and yields secured from the weight relationship of five bundles and the entire plat.

[5]FISHER, R. A. Statistical Methods for Research Workers. Edinburgh: Oliver & Boyd. Ed. 6. 1936.

[6]See footnote 3.

REGRESSION LINES

The regression lines recorded in Table 2 are derived from the relationship existing between actual plat yields and yields estimated from the various harvesting methods. These lines point out very clearly the comparative degree of closeness of fit to the line Y = X, a line denoting unit changes in X and Y values. The fact that the regression lines secured from the weight relationships are very close to the line Y = X and in the case of the "three bundle" method of harvest practically coincident with it and in contrast all regression lines secured from the area methods of harvest are rather widely divergent from the line Y = X, show the superiority of a weight relationship method of harvest. Figs. 1 and 2 further illustrate the fact that the weight relationship method of harvest gives yields nearer to actual plat yields than does the area method.

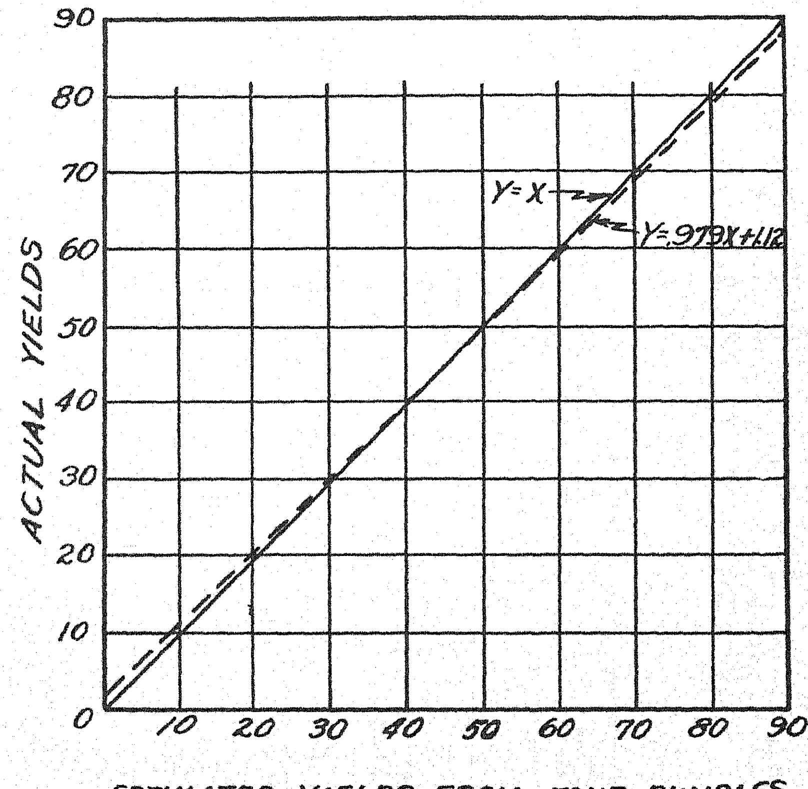

FIG. 1.—A comparison of the regression line and the line Y = X estimated from bundle yields.

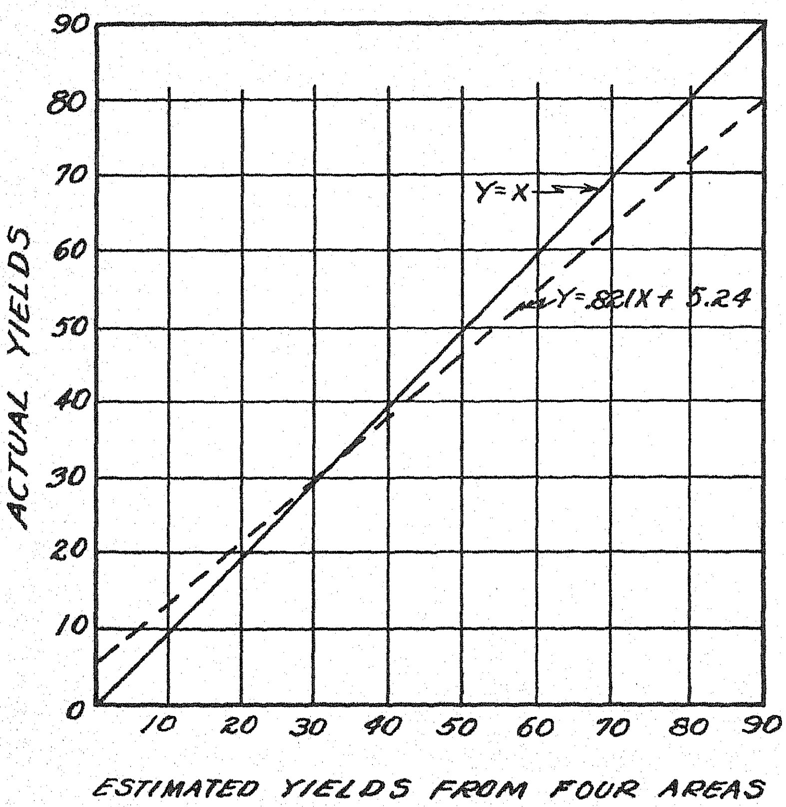

FIG. 2.—A comparison of the regression line and the line Y = X estimated from area yields.

TABLE 2.—*Regression lines and standard errors of estimate and errors of estimate from the line $Y=X$.*

Methods of harvest	Regression lines	Standard errors of estimate	Errors of estimate from line Y = X
5 bundles threshed...	$\bar{y}$ = .970x + 1.40	2.360	2.401
4 bundles threshed...	$\bar{y}$ = .979x + 1.12	2.373	2.412
3 bundles threshed...	$\bar{y}$ = 1.00x + 0.14	2.869	2.840
2 bundles threshed...	$\bar{y}$ = .953x + 3.15	3.453	3.534
1 bundle threshed....	$\bar{y}$ = .930x + 3.75	3.816	3.920
6 areas threshed.....	$\bar{y}$ = .783x + 8.57	4.700	7.630
5 areas threshed.....	$\bar{y}$ = .782x + 8.50	4.663	7.729
4 areas threshed.....	$\bar{y}$ = .821x + 5.24	4.785	8.55
3 areas threshed.....	$\bar{y}$ = .750x + 10.38	4.230	7.857
2 areas threshed.....	$\bar{y}$ = .601x + 21.04	5.494	8.265
1 area threshed......	$\bar{y}$ = .610x + 19.37	5.832	9.402

STANDARD ERRORS OF ESTIMATE AND ERRORS OF ESTIMATE FROM THE LINE Y = X

The standard errors of estimate from the regression lines found in Table 2 indicate again that the weight relationship methods of harvest

give yields that compare more closely to actual yields than do yields secured from the area methods of harvest. When the yields are estimated from five bundles the standard error of estimate is 2.36 bushels. As the number of bundles threshed decreases the standard error of estimate consistently increases to 3.82 bushels for yields based on one bundle. The standard errors of estimate for the area methods are greater, ranging from 4.70 bushels for six "cut-out" areas to 5.832 bushels for one "cut-out" area. It should be noted the error for six "cut-out" areas is approximately 0.9 bushel greater than for one bundle. Two advantages, then, are found in favor of cutting the grain with the binder. Not only do the yields conform more closely to the actual plat yields, but the amount of labor involved in harvesting is also materially lessened.

A more logical comparison can be made if errors are calculated from the line Y=X since this line represents perfect agreement with actual plat yields. When these errors are calculated it serves to accentuate the differences between the harvesting methods. For the "bundle" method of harvest this value varies from 2.40 bushels to 3.92 bushels and for the area methods from 7.63 bushels to 9.40 bushels, showing again the superiority of the bundle method of harvest over the area method. Referring to the "Z" values and the "t" values in Table 3, calculated to show the significant differences between the standard errors both from the lines of best fit and the line Y=X, it is found in all cases at the 5% point that the yields based on five threshed bundles are significantly better than yields based on one bundle threshed or any yields calculated from small cut-out areas. Also, the yields from the five threshed bundles are significantly different than any yields secured from area methods of harvest at the 1% point, indicating again that yields estimated from weight relation-

TABLE 3.—*Z values and t values for differences between standard errors of estimate and Z values for differences between errors from the line Y=X of five threshed bundles and other methods of harvest.*

Method of harvest	Z value for errors of the line Y=X*	Z values of standard errors of estimate	t values of standard errors of estimates†
4 bundles threshed	.004	.005	.031
3 bundles threshed	.168	.195	1.092
2 bundles threshed	.387	.380	1.133
1 bundle threshed	.490	.480	2.588
6 areas threshed	1.156	.689	3.551
5 areas threshed	1.168	.680	3.516
4 areas threshed	1.269	.707	3.624
3 areas threshed	1.185	.583	3.076
2 areas threshed	1.236	.845	4.178
1 area threshed	1.365	.904	4.553

Z (5% point) .459
Z (1% point) .659
t (5% point) 2.048
t (1% point) 2.763

$$*Z = \frac{1}{2} \log_e \frac{(\sigma\ e \text{ of line } Y=X \text{ of treatment compared})}{(\sigma\ e \text{ of line } Y=X \text{ of 5 bundles threshed})}.$$

†The t values were calculated from the following formula: $t = \dfrac{\sigma e_1 - \sigma e_2.}{\dfrac{S}{\sqrt{2N}}}$ This formula was derived by Professor W. D. Baten, who has not yet published his findings.

ships are closer to the actual yields than when the yields are secured from "cut-out" areas. No significant differences were found between yields based on five threshed bundles and yields obtained from four, three, or two threshed bundles, indicating that probably yields based on two or three threshed bundles are nearly as reliable as those secured from five bundles.

Likewise, according to these data, increasing the number of "cut-out" areas would not materially increase the reliability of the results if yields are to be calculated from small areas cut out by hand. It is also very interesting to note that the "Z" test and the "t" test for the comparisons of the standard errors of estimate between the results from five bundles threshed and other methods of harvest show the same degree of significance in every case. The differences that are significant at the 5% point and the 1% point for the "Z" values are also significant according to the "t" test applied.

The main question to be considered in any work dealing with a comparison of methods is whether in using one method the estimated results vary far enough from the actual yields of the plats to give erroneous conclusions. For this reason Table 4 is presented.

An examination of Table 4 is quite convincing as to closer association of results with the actual when these results are estimated from weight relationships rather than from area relationships. The argument is often made that comparative results between treatments are all that is required and the true yield of any plat is not essential providing the method of taking yields is essentially the same for all plats. The data indicate, however, that in order to get comparable results from a series of treatments a great deal of dependence would have to be placed upon compensating errors in order to arrive at results that would give this comparison between treatments if small "cut-out" areas are used. The significance of the results in Table 4 is demonstrated in the consideration of the magnitude of the errors from the line $Y=X$ of the various harvesting methods. As previously stated, the larger this error becomes the more divergent the calculated plat yields are from the actual plat yields. This point has previously been discussed.

An examination of Table 5 indicated that the statistical constants obtained from a random area do not differ materially from the corresponding constants secured from a systematically selected area. In no case does a significant difference exist between constants derived from either method.

CONCLUSIONS

Yields obtained on three types of harvesting methods were secured from a series of oat plats. In the first method the entire plat was cut and threshed; in the second, yields were calculated from small areas cut-out with a hand sickle; while in the third, yields were obtained from the grain-straw ratio in a portion of the plat and the bundle weight of the entire plat.

Higher values for "r" and "Z" were obtained when actual plat yields were compared to yields calculated from weight relationships than from area relationships.

TABLE 4.—*Actual plat yields and plat yields calculated by the various harvesting methods.**

Method of harvest	Plat No.															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Entire plat yield	62.5	58.2	40.4	36.4	61.0	66.0	59.4	65.6	57.7	57.3	66.1	63.0	55.8	60.7	65.5	59.6
5 bundles threshed	64.6	57.1	43.8	37.4	67.7	64.4	59.1	66.6	55.7	54.8	66.5	63.1	54.7	59.9	66.6	58.8
4 bundles threshed	62.7	57.6	43.6	37.4	67.7	64.4	59.3	68.1	55.7	55.1	65.4	62.7	53.4	59.9	65.2	59.2
3 bundles threshed	61.6	57.9	44.0	37.9	68.5	64.1	58.5	67.0	55.1	55.0	64.2	61.3	54.2	58.1	64.0	61.6
2 bundles threshed	62.0	56.6	45.5	36.9	67.7	63.6	54.5	68.2	52.6	56.3	62.2	65.0	55.9	56.6	64.8	60.5
1 bundle threshed	59.3	59.0	46.4	38.5	66.5	67.5	55.1	64.5	53.4	54.1	70.4	67.4	59.0	56.9	61.5	61.7
6 areas threshed	70.7	60.5	51.9	40.3	60.7	70.1	69.3	62.3	61.7	59.3	75.2	68.2	62.3	59.5	72.7	75.8
5 areas threshed	69.1	61.3	51.2	39.6	61.1	69.8	71.9	61.5	64.4	58.9	75.7	68.1	62.5	59.6	73.5	73.5
4 areas threshed	74.3	60.7	53.6	42.7	59.8	69.3	64.5	65.4	63.6	65.1	76.9	67.2	62.8	61.3	74.3	76.0
3 areas threshed	71.5	62.1	51.5	38.9	60.1	73.1	72.7	66.4	61.3	54.2	77.8	68.4	60.9	62.5	74.3	70.3
2 areas threshed	63.6	60.1	46.0	35.4	62.5	71.9	79.0	56.1	57.8	59.6	71.9	70.2	61.3	56.1	69.5	75.4
1 area threshed	70.7	69.5	58.9	35.4	56.6	75.4	64.8	66.0	74.3	50.7	70.7	69.5	57.8	61.3	74.3	69.5

*Yields are expressed in bushels per acre.

TABLE 5.—*Comparison of results secured from one area selected at random and one area selected systematically.*

Statistical constant	Random selection	Systematic selection
r	.7230	.7500
Z	.9139	.9730
Mean difference, Z	$1.0796 \pm .3922$	$1.0205 \pm .3922$
Regression line	$\bar{y} = .587x + 21.73$	$\bar{y} = .610x + 19.37$
Standard error of estimate	5.885	5.832
Error of estimate from line $Y = X$	8.77	9.402
Difference in Z values from five bundles threshed and one area threshed	.948	.904

The regression lines obtained from the weight relationships compared more closely in all cases to the line $Y = X$ than did the regression lines obtained from the area methods of calculating yields.

The standard errors of estimate and the errors of estimate from the line $Y = X$ varied significantly between all area methods and the method in which the weight relationship of five bundles to the total grain and straw weight of the entire plat was used. The errors for the yields based on one bundle were significantly greater than the errors for yields based on five bundles. The magnitude of the errors in every case was considerably lower when yields were calculated from weight relationships than from the area methods.

The calculated yields varied progressively from the actual plat yield with the decrease in the number of bundles weighed and with the number of areas cut, but the yields from one bundle were closer to the actual plat yields than when yields were based on six areas.

From the data presented, it would appear that three bundles weighed from a plat of this particular size would give a very accurate estimate of the plat yields and would be the recommended number to use in yield estimation.

A harvested area as small as 1,000 square feet has been satisfactorily taken care of by this method.

When compared to the method of cutting out small areas, the grain-straw ratio method of harvest has the advantage of being more accurate and more efficient in the use of labor. An experiment consisting of 108 plats of oats was harvested in 4½ hours. Four men were required to do the work, two of the men were required to run the binder since the tractor did not have a power take-off. The amount of hand labor involved is materially lessened since the grain is cut with the binder.

THE DECOMPOSITION OF ORGANIC MATTER IN SOILS AT DIFFERENT INITIAL pH[1]

R. S. DYAL, F. B. SMITH, AND R. V. ALLISON[2]

ONE of the most important environmental conditions influencing the activities of soil micro-organisms is the hydrogen-ion concentration of the soil. It affects not only the rates of many of the physiological processes, the rates of growth and respiration, but also the types of organisms developing. The anion or the undissociated molecule of certain acids may be as effective as the hydrogen ion in increasing or decreasing microbiological action. However, there is considerable evidence which indicates that the beneficial effect of applications of lime to acid soils is due largely to the change in reaction brought about.

Numerous investigators have reported the effects of hydrogen-ion concentration on the growth or metabolic processes and the occurrence of specific organisms. Johnson (3)[3] in a study of the relationships between hydrogen ion, hydroxyl ion, and salt concentration and the growth of seven soil molds, obtained growth over a considerable range in pH. Itano (2) in a study of the effect of the initial hydrogen-ion concentration on the rate of proteolysis by *B. subtilis* in a peptone meat extract broth found the rate of growth to be most rapid at a pH of 6.66 and the rate of ammonia formation most rapid at pH 5.42 after 240 hours. Brooks (1) investigated the effect of hydrogen-ion concentration on the production of carbon dioxide by the tubercle bacillus and found no change in the production of carbon dioxide from pH 4.4 to pH 7.4 but there was a decrease in carbon dioxide production above and below these pH values.

Much of the earlier work in soils along these lines has been concerned with the effects of applications of lime on the numbers of bacteria or on the action of certain physiological groups. Waksman and Starkey (9) found that additions of lime stimulated the respiratory capacity of the soil and brought about an increase in the numbers of bacteria. Waksman and Heukelekian (8) found no correlation between the reaction of the soil and its cellulose decomposing power. However, it was explained that the fungi which are active cellulose decomposers grow well in acid soils. White, Holben, and Jeffries (10) have shown that corn starch was decomposed at about the same rate in acid as in alkaline soils, but that cellulose, manure, and cottonseed meal were decomposed more rapidly in limed than in acid soils. Lime added to acid soils stimulated carbon dioxide production and increased the numbers of micro-organisms. Smith and Brown (7) investigated the influence of substituted cations in the complex of Tama silt loam on the rate of decomposition of leguminous green manures and found that the rate of decomposition was least rapid in

[1]Contribution from the Department of Chemistry and Soils, University of Florida, Gainesville, Florida. Received for publication July 26, 1939.
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[3]Figures in parenthesis refer to "Literature Cited", p. 850.

the hydrogen saturated soil (pH 5.11) and most rapid in the magnesium soil (pH 6.43).

While many of the investigations reported give data in terms of hydrogen-ion concentration and some are directly related to the decomposition of organic matter, few of them were designed to study the effect of hydrogen-ion concentration on the decomposition of organic matter in soils. The purpose of the work reported here was to study the effect of reaction of the soil on the decomposition of various green plant materials in Norfolk loamy fine sand.

METHODS OF PROCEDURE

The soils of a series of reaction plats[4] of the Department of Chemistry and Soils of the Florida Agricultural Experiment Station were employed in this study. The treatments and pH of these soils are given in Table 1. A 2-quart sample of the top soil to a depth of 6 inches was taken from each of the plats Nos. 1, 2, 5, 8, 9, 10, and 12, air-dried, and screened through a 20-mesh sieve. Each soil was thoroughly mixed and the pH and water-holding capacity determined. Duplicate 250-gram portions of the soils were treated in 1-liter filter flasks with organic matter in four series as follows: Series I, green crotalaria; series II, green natal grass; series III, green natal grass and potassium nitrate; and series IV, green natal grass.

TABLE 1.—*The treatment, organic matter content and pH of soils of the reaction plats.*

Plat No.	Treatment in pounds per acre						pH	Organic matter* %
	Material	1926	1931	1935	1937	1938		
1	Sulfur	1,000	900	500	500	500	3.71	1.20
2	Sulfur	500	450	250	250	250	4.59	1.08
5	Limestone	2,000	900	1,000	1,000	1,000	6.33	0.86
8	Sulfur	500	450	250	250	250	4.26	1.02
9	No treatment	—	—	—	—	—	5.94	1.00
10	Limestone	1,000	450	500	500	500	6.50	0.94
12	Limestone	4,000	1,800	2,000	2,000	2,000	7.05	1.20

*Loss on ignition.

The *Crotalaria spectabilis* was taken from the Florida Agricultural Experiment Station farm when the plants were in the early bloom stage. The natal grass (*Tricholaena rosea*) was harvested at two stages of growth. In series II, designated as natal grass No. 1, the mature grass was used; and in series III and IV, designated as natal grass 2 and 3, respectively, the younger, vegetative grass was used. In series III sufficient potassium nitrate was added to each soil to make the total nitrogen content equal to that in series I where crotalaria was used.

The green plant materials were ground coarsely in a food chopper and mixed. One portion was then dried in an oven at 60° C. When the materials were dry they were ground in a Wiley mill and a subsample of each reduced in a Dreef pestle mill to pass a 60-mesh sieve. The subsamples were preserved for later analyses. The moisture content of the green plant materials was determined by drying in an electric oven for five hours at 110° C. Additions of the moist, green materials equal to 1% dry weight were made to the soils. The soil and the plant

[4]Established in 1926 by Dr. O. C. Bryan and now under the supervision of H. W. Winsor.

material were mixed thoroughly and the moisture content of the soils adjusted to 50% of the saturation capacity. The soils were incubated at room temperature and the carbon dioxide evolved was determined by aspiration with carbon dioxide-free air at regular intervals.

The apparatus used is shown in Fig. 1. A pressure pump was used to force air and sodium hydroxide into the bead tower. The air and sodium hydroxide ran

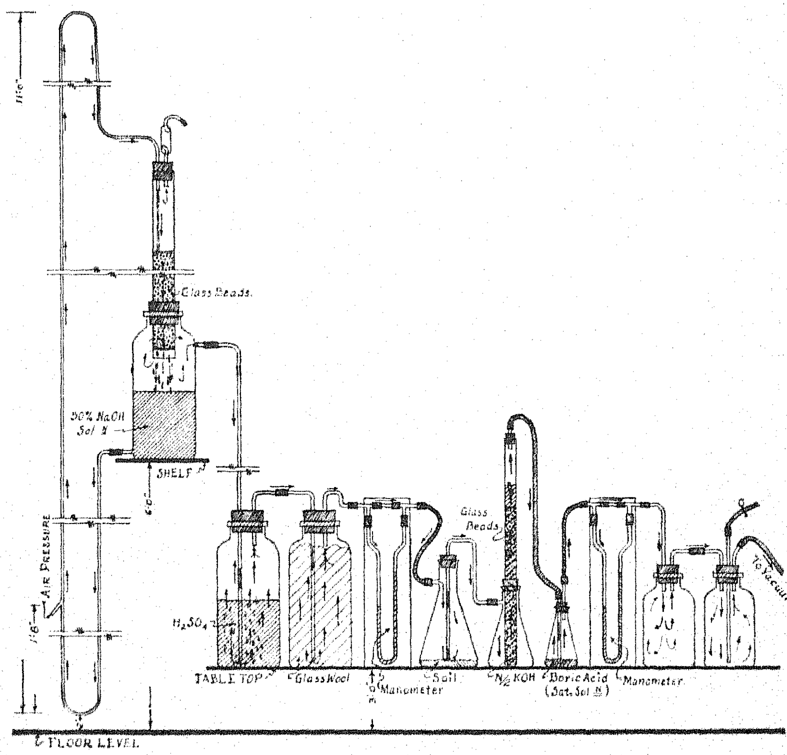

FIG. 1.—Apparatus used to determine carbon dioxide production.

down over the beads, freeing the air of carbon dioxide. The carbon dioxide-free air was then taken at atmospheric pressure by the vacuum from the top opening on the side of the sodium hydroxide bottle. Thus, the back pressure on the gas train was reduced to a minimum. The rate of aspiration was regulated at 4 liters per 30 minutes by means of manometers. The carbon dioxide was absorbed in ½ N potassium hydroxide. Barium chloride was used to precipitate the carbon dioxide and the excess potassium hydroxide was titrated with standard hydrochloric acid, using phenolphthalein as the indicator.

The experiment was discontinued when the amount of carbon dioxide produced during a given interval was about the same in the different soils. This was 20 days after the beginning of the experiment in series I, 28 days in series II, and 20 days in series III and IV.

After the carbon dioxide determinations were discontinued, the pH of the soils was determined by the quinhydrone electrode, and the moisture content by drying in the oven at 110° C for 5 hours.

The nitrification of crotalaria and the nitrification of ammonium sulfate in soils treated with natal grass were determined in a series of tumbler experiments. Duplicate 200-gram portions of the soils were treated with 4 grams of the finely ground plant materials and in the case of natal grass 30 milligrams of nitrogen as ammonium sulfate were added in solution. The moisture content of the soils was adjusted to 60% and maintained at that amount by frequent additions of distilled water. The tumblers were placed in the incubator at room temperature for 30 days after which the pH and nitrate content of the soils were determined. The nitrate nitrogen was determined by the phenoldisulfonic acid method.

A proximate analysis of the plant materials determining the ether-soluble fraction, sugars, starches, hemicellulose, and cellulose was made by a method proposed by Leukel, et al. (4). The lignin was determined by a modification of the Ritter, Seborg, and Mitchel (5) method. The nitrogen was determined by the Hibbard modification of the Gunning-Kjeldahl method, distilling the ammonia into boric acid as proposed by Scales and Harrison (6). The ash was determined by igniting to dull red heat in an electric muffle furnace.

RESULTS

CARBON DIOXIDE PRODUCTION

The total carbon dioxide production during the period of 20 days in soils treated with the green plant materials is shown in Fig. 2.

The data show that the amounts of carbon dioxide produced in the soils treated with crotalaria at pH values 3.71, 4.26, and 4.59 were of about the same magnitude and averaged slightly less than that of the soils at the higher pH values. The average difference in total carbon dioxide production in the two groups of soils was not great during the first few days of the experiment. However, after about four days there was a larger difference, indicating a somewhat more rapid decomposition of the crotalaria in the soils of a higher pH value. The pH values of the soils before and after treatment with crotalaria and incubation are presented in Table 2.

The pH of the soils treated with the crotalaria increased in every case, except in the soils at pH of 5.94, 6.50, and 7.05 in which cases there were slight decreases in pH. All of the untreated soils decreased in pH during the experiment, except the soil at pH 3.71 which increased to pH 3.76.

The decomposition of the mature natal grass increased with an increase in the pH of the soil from a pH of 3.71 to a pH of 6.50. The amount of decomposition of this material in the soil at pH 7.05 was slightly less than that in the soils at pH 6.33 and 6.50 but considerably greater than that in the soils at pH 5.94 or below. The amount of carbon dioxide produced in the soils at pH 4.59 or below was considerably less than the amount produced in the soils at pH 5.94 or above.

The pH of the soils treated with natal grass No. 1 increased in every case, except in the soil at pH 5.94 where it decreased to pH 5.75 (Table 2). The untreated soils in series II decreased in pH in every case.

The largest total production of carbon dioxide in the soils treated with natal grass and potassium nitrate was obtained in the soil at pH 7.05. The smallest total production of carbon dioxide and the least decomposition was obtained in the soils at pH 3.71. The rate of

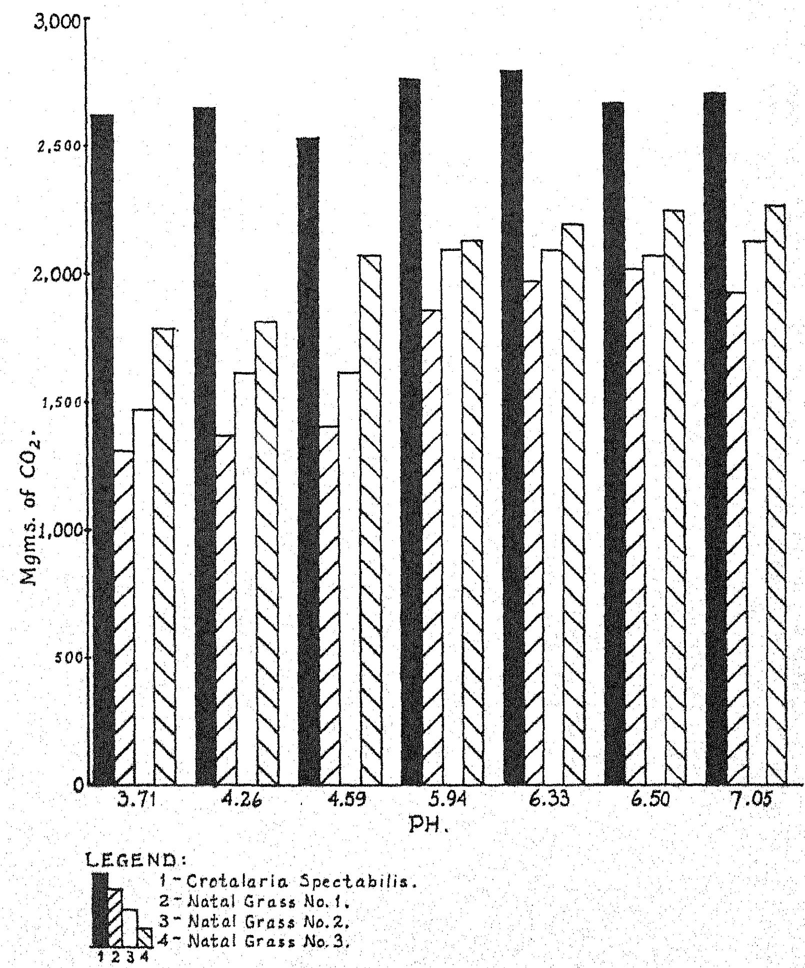

FIG. 2.—Carbon dioxide production in soils of different initial pH.

decomposition during the first three days of the experiment was about the same in all soils. However, after the fourth day the rate of decomposition was considerably more rapid in the soils at pH 5.94, 6.33, 6.50, and 7.05 than in the soils at pH 3.71, 4.26, and 4.59. The pH of the soils was decreased during the experiment where decomposition was most rapid, except in the case of the soil at pH 7.05 where it was increased (Table 2).

TABLE 2.—*The pH of soils before and after incubation.*

Soil No.	pH at beginning	pH at end of decomposition period				pH after nitrification				
		Crotalaria	Natal grass No. 1	Natal grass No. 2	Natal grass No. 3	Crotalaria	Natal grass No. 1	Natal grass No. 1+30 mgms N as $(NH_4)_2SO_4$	Natal grass No. 2	Natal grass No. 2+30 mgms N as $(NH_4)_2SO_4$
1	3.71 a*	6.84	4.58	5.23	4.85	6.92	4.69	4.50	5.72	5.64
	b	3.76	3.68			4.06				
8	4.26 a	6.70	4.90	5.56	5.90	6.52	5.82	4.58	6.26	5.50
	b	4.19	3.92			4.46				
2	4.59 a	6.72	5.26	5.28	5.49	6.07	5.12	4.45	5.98	5.60
	b	4.10	4.09			4.49				
9	5.94 a	5.65	5.75	5.84	5.68	6.01	6.85	4.85	6.41	5.58
	b	4.98	4.67			5.25				
5	6.33 a	6.58	6.75	5.35	6.62	6.22	6.80	4.80	6.41	5.26
	b	5.64	5.83			6.71				
10	6.50 a	6.02	6.75	6.25	6.32	6.48	6.77	5.00	6.79	5.34
	b	5.96	5.94			6.38				
12	7.05 a	6.68	7.42	7.50	7.06	7.03	7.71	5.68	7.60	5.82
	b	6.80	6.56			7.12				

*a, soils treated with plant material; b, untreated soils.

The amount of decomposition of natal grass No. 3 increased with an increase in pH of the soil from pH 3.71 to pH 7.05. The average total decomposition at pH 3.71 to pH 4.59 was considerably less than the average decomposition in the soils at pH 5.94 to 7.05.

NITRIFICATION

The results of the nitrification experiments are presented in Table 3. The nitrate content of the untreated soils was relatively small in all cases but largest in the soil of pH 5.94 and smallest in the soil of pH 3.71. The nitrate content of the crotalaria-treated soils was higher at all pH values than that of any other treated soils, except that of the soil of pH 3.71 treated with natal grass and ammonium sulfate. The nitrification of crotalaria was considerably reduced in the soils of pH 3.71, 4.26, and 4.59. This was no doubt caused by the harmful effect of the acidity on the nitrifying organisms and, no doubt at least partly, by the types or kinds of micro-organisms decomposing the crotalaria in these soils. The maximum nitrification of the crotalaria was obtained in the soils of pH 6.33. The next largest nitrification of crotalaria was obtained in the soils of pH 5.94. In general, the nitrification of crotalaria was fairly high in all soils of pH 5.94 to 7.05 and relatively low in the soils of pH 3.71 to pH 4.59.

TABLE 3.—*The effect of crotalaria and natal grass on nitrification in Norfolk loamy fine sand at different pH values, p.p.m. of nitrate nitrogen.*

pH of soil	Check	Crotalaria	Natal grass No. 1	Natal grass No. 1+30 mgm. N as $(NH_4)_2SO_4$	Natal grass No. 2	Natal grass No. 2+30 mgm. N as $(NH_4)_2SO_4$
3.71	Trace	Trace	0	0	0	6.76
4.26	3.44	26.68	0	0	0	5.23
4.59	4.06	24.53	0	Trace	Trace	5.30
5.94	4.22	80.52	0	Trace	Trace	6.00
6.33	3.52	100.00	0	28.56	Trace	41.30
6.50	2.66	65.97	0	3.68	3.80	21.50
7.05	2.85	66.63	0	18.02	Trace	22.14

The soils treated with natal grass No. 1 without additions of ammonium sulfate contained no nitrate. This was probably caused by the organisms utilizing all of the available nitrogen in the decomposition of the natal grass.

The soils treated with natal grass No. 1 plus 30 milligrams of nitrogen as ammonium sulfate contained no nitrates at pH 3.71 and 4.26 and the soils of pH 4.59 and 5.94 contained only a trace of nitrate nitrogen. The treated soil at pH 6.33 contained the largest amount of nitrate nitrogen of any soil in this series. The low nitrate content of the soils of pH below 6.33 may be explained by the kind of micro-organisms, the type of organic matter, and the acid condition of the soils.

The soils treated with natal grass No. 2 contained no nitrates at pH 3.71 and 4.26. All of the other treated soils contained only a trace of nitrates, except the soils at pH 6.50 which contained only 3.80 p.p.m.

All of the soils treated with natal grass No. 2 plus an addition of nitrogen as ammonium sulfate contained nitrates. The nitrification of ammonium sulfate in these soils was considerably less at pH values below 5.94 than at pH values of 6.33 to 7.05, the largest nitrification occurring in the soil at pH 6.33. These data seem to indicate a different type of decomposition and certainly different rates of decomposition at pH values of 5.94 or below from that obtained at the higher pH values. The pH of the soils in the nitrification experiments is presented in Table 2.

The data show that the pH of the soils treated with crotalaria was not changed as much as the pH of the soils treated with natal grass and ammonium sulfate. Apparently these changes in the pH of the soils during nitrification were caused by the nitric acid produced and in the case of the ammonium sulfate treated soil also to the residual sulfuric acid that developed during the process. In general, the greatest change in pH occurred in the soils in which nitrification was most pronounced.

ANALYSES OF PLANT MATERIALS

The analyses of the crotalaria and the natal grass used in these experiments are given in Table 4. All three plant materials contained relatively small percentages of the ether-soluble fraction, sugars, and starches. The mature natal grass (No. 1) contained larger amounts of the hemicellulose, cellulose, and lignin fractions and considerably less protein, ash constituents, and moisture than the crotalaria or the natal grass No. 2. The crotalaria contained the smallest percentage of lignin and the largest percentages of protein and water.

TABLE 4.—*Analyses of plant materials.*

Constituent	Crotalaria	Natal grass No. 1	Natal grass No. 2
Ether soluble	1.89	1.38	2.36
Total sugars	1.94	1.24	1.44
Starch	1.19	0.64	0.96
Hemicellulose	10.86	26.64	19.51
Cellulose	21.13	29.44	26.80
Lignin	14.47	18.26	17.75
Protein	16.65	3.97	9.38
Ash	6.27	5.65	10.61
Moisture	79.00	53.97	70.20

DISCUSSION OF RESULTS

There were slightly smaller amounts of carbon dioxide produced in the crotalaria-treated soils at pH 3.71, 4.26, and 4.59 than in the soils at pH 5.94, 6.33, 6.50, and 7.05. Possibly the reason why one soil decomposed the crotalaria about as readily as another was because of the increase in pH of the soils. The pH of the soils increased from 3.71, 4.26, and 4.59 at the beginning of the experiment to 6.84, 6.70, and 6.72 at the end of the incubation period. It is apparent, therefore, that the decomposition of the crotalaria in this soil was not taking place at pH 3.71.

The increase in the pH of these soils may be explained, at least partly, by free ammonia which might have been present and carbonic

acid. The carbonic acid might possibly increase the pH of the soil by the dilution of a stronger acid in a poorly buffered solution.

The natal grass No. 1 decomposed more readily in soils at pH values of 5.94, 6.33, 6.50, and 7.05 than in the soils at pH 3.71, 4.26, and 4.59.

The less rapid decomposition of the natal grass No. 1 in the soils of initial pH 3.71, 4.26, and 4.59 than in the soils at the higher pH values was undoubtedly caused by a detrimental effect of the increased acidity on the growth of the decay bacteria. Also the types of bacteria present in the soils of pH values 3.71, 4.26, and 4.59 were apparently different from those found in the soils at the higher pH values. The nitrogen content of the mature natal grass was not sufficient to permit the formation of nitrates as was revealed by the nitrification studies. The low nitrogen content and the relatively high content of hemicellulose, cellulose, and lignin were also factors in the slow decomposition of the natal grass.

The decomposition of natal grass No. 2 was more rapid in soils at pH values of 5.94, 6.33, and 7.05 at the beginning than in the soils at the lower pH values. The acidity of the soils at pH 3.71, 4.26, and 4.59 apparently inhibited the growth of the micro-organisms. The increase in pH of these soils was possibly caused by the potassium nitrate added to the soils. The micro-organisms used the nitrate and the potassium was left free to act as a basic residue to increase the pH of the soil.

The largest decomposition of natal grass No. 3 occurred in the soils of pH 7.05 and the least amount of decomposition was obtained in the soils at pH 3.71. This difference in the decomposition of the natal grass No. 3 may be attributed to the difference in numbers of micro-organisms in the soil and the retarding effect of the increased acidity at the lower pH values. Because of the low protein content of the natal grass the micro-organisms were not able to free any of the nitrogen as ammonia, consequently no nitrification of the natal grass occurred.

The total amount of carbon dioxide produced was largest in the soils treated with the crotalaria and smallest in the soil treated with the natal grass No. 1. There was a larger total production of carbon dioxide in the soils treated with the succulent natal grass No. 3 than in the soils treated with the more mature natal grass No. 1. There is no apparent reason why the natal grass No. 2 should have decomposed more slowly than the natal grass No. 3, unless the potassium nitrate added proved toxic to the micro-organisms in the concentration used.

SUMMARY AND CONCLUSIONS

Four series of experiments were conducted on the decomposition of green crotalaria and green natal grass harvested at two different stages of growth in soils of varying degrees of acidity from pH 3.71 to pH 7.05. The results obtained may be summarized briefly as follows:

1. All plant materials decomposed more rapidly and more completely in soils at pH 5.94 to 7.05 than at pH 3.71 to 4.59.

2. The detrimental effect of acidity on decomposition was more pronounced in soils treated with natal grass than in soils treated with crotalaria.
3. The acidity of the soils treated with crotalaria was decreased markedly in the soils at low pH in the beginning of the experiment. This decrease in acidity of the soil was possibly caused by the liberation of ammonia or the dilution effect of carbonic acid or both. It can hardly be claimed that the full effect of the acidity of these soils on the decomposition of crotalaria was measured in these experiments.
4. The addition of nitrogen as potassium nitrate to the natal grass-treated soils in an amount sufficient to bring the total nitrogen content of these soils to that of the crotalaria-treated soils did not increase the decomposition of the natal grass.
5. The decreased nitrification in the soils at pH 3.71, 4.26, and 4.59 was undoubtedly brought about by the micro-organisms utilizing the ammonia in the decomposition of the carbonaceous materials and also partly by the detrimental effect of the increased acidity on the nitrifying bacteria. A deficiency of available calcium in the strongly acid soils could possibly have caused this decreased nitrification observed in the soils at low pH.
6. The plant materials containing the larger percentages of the hemicellulose, cellulose, and lignin fractions decomposed more slowly than those containing the smaller percentages of these constituents.

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MILLING, BAKING, AND CHEMICAL PROPERTIES OF COLORADO-GROWN MARQUIS AND KANRED WHEAT STORED 9 TO 17 YEARS[1]

D. W. Robertson, C. C. Fifield, and Lawrence Zeleny[2]

CURRENT interest in long-time storage of wheat suggests the need for information with respect to the relation between length of storage and quality. It is well known that any damage such as will affect the commercial grade is likely to affect the quality deleteriously, but information with respect to possible deterioration when wheat is stored dry and free from insect damage is decidedly deficient. Wheat from the 1921 and later crops stored under such conditions by the Colorado Agricultural Experiment Station for the purpose of studying the relation of age to viability appeared to afford an unusual opportunity to study this relation. Accordingly, samples of those lots were milled and baked in the Milling, Baking, and Chemical Laboratory of the Bureau of Agricultural Economics in cooperation with the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, in 1938.[3] The purpose of this paper is to present such of the resulting data as will be of interest. Robertson and Lute[4] have reported on the germination of the samples and have given the pertinent facts regarding their storage.

MATERIALS AND METHODS

Briefly, the studies herein reported were limited to Marquis spring wheat grown under irrigation and Kanred winter wheat grown on fallow without irrigation. After threshing and cleaning, the grain was stored in 100-pound sacks in a dry, unheated room. The annual precipitation and average annual humidity at Fort Collins are given by Robertson and Lute[5] and the possible relation of these to storage is also discussed by these authors. The moisture content of the grain at time of storage was not determined but is believed to have been relatively low.

Samples of Marquis representing eight crops from the years 1921 to 1929 and of Kanred representing three crops from the years 1921, 1924, and 1929 were milled and the flour baked into bread.

The tempered wheats were milled on an Allis-Chalmers experimental flour mill provided with three pairs of break rolls and one pair of smooth rolls. (See U. S. Dept. of Agr. Tech. Bul. No. 197 for complete description of milling equipment and operative technic). Chemical tests (moisture, ash, and protein) were made by

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[1]Contribution from the Department of Agronomy, Colorado Agricultural Experiment Station, Fort Collins, Colo. Received for publication July 27, 1939.

[2]Agronomist, Colorado Agricultural Experiment Station, Associate Baking Technologist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, and Associate Grain Technologist, Grain Division, Bureau of Agricultural Economics, respectively.

[3]Credit is due H. C. Fellows, J. F. Hayes, Elwood Hoffecker, Ray Weaver, B. E. Rothgeb, and M. H. Newstadt of the Milling, Baking, and Chemical Laboratory for making some of the determinations reported in this paper.

[4]Robertson, D. W., and Anna M. Lute. Germination of seed of farm crops in Colorado after storage for various periods of years. Jour. Amer. Soc. Agron., 29:822–834. 1937.

[5]*Loc. cit.*

accepted and approved methods of the American Association of Cereal Chemists. Acidity was determined on the extracted fat constituents of the wheat by the method suggested by Zeleny and Coleman.[6] The fat acidity values are expressed in terms of the number of milligrams of potassium hydroxide required to neutralize the free fatty acids from 100 grams of wheat ascertained on a dry matter basis.

Bread baking tests were made by the straight dough method, employing the baking formula ingredients most commonly used by commercial bakers. For this purpose three formulas were employed, namely, (1) commercial, using 100 grams flour, 5.0 grams sugar, 1.5 grams salt, 2.0 grams yeast, 3.0 grams shortening, 4.0 grams dried skimmilk, and sufficient water to form a dough of proper consistency; (2) commercial-bromate, same as formula No. 1, plus 1 mg of potassium bromate; and (3) a second commercial formula the same as formula No. 1 except the amount of yeast was increased to 3.0%. The milling, baking, and chemical results are shown in Table 1. The loaves baked from Marquis are shown in Fig. 1 and those from Kanred in Fig. 2.

EXPERIMENTAL RESULTS

Good flour yields were obtained from all samples, none being less than 69.3% obtained from the 1925 Marquis, which can be accounted for by the low (57.8 pounds) test weight. None of the lots required special tempering treatment or special handling in the mill to secure optimum flour yields.

The protein content varied from 11.3% for Marquis harvested in 1925 to 14.4 and 14.5% for the 1921 and 1927 crops, respectively. Kanred ranged from 12.9 to 14.3%. None of the samples, with the possible exception of the 1925 Marquis, can be considered too low in protein for good bread.

Fat acidity values on Marquis ranged from 26.2 for the 1929 samples to 47.7 for the 1921 samples and on Kanred from 26.7 for the 1929 samples to 37.5 for the 1921 samples. Unquestionably, the higher fat acidity values on the 1921 samples indicate that some deterioration has taken place during the long storage period. It has been demonstrated[7] that fat acidity values range from less than 20 for freshly harvested sound wheat to 70 or more for badly deteriorated wheat and may be used as an approximate index of the degree of deterioration the wheat has undergone. Broadly speaking, while values of 50 or less are not ordinarily associated with impaired milling or baking quality of the freshly milled flour, preliminary evidence indicates that flour milled from wheat having acidity values of approximately 50 or more will deteriorate in baking quality during storage more rapidly than will flour from wheat of lower acidity.

Gassing power determinations made on the flour as an indication of the raw starch amylase or susceptible starch available for use during the fermentation period reveal marked differences for the lots harvested in different years. The 1921 and 1925 crops of Marquis were definitely superior in gassing power to those of 1923, 1927, or

[6]ZELENY, LAWRENCE, and COLEMAN, D. A. Acidity in cereal and cereal products, its determination and significance. Cereal Chem., 15:580–595. 1938.
[7]ZELENY, LAWRENCE. Unpublished data.

1929. For Kanred the values were highest in 1921 and lowest in 1929. It is not apparent from these data that long storage is associated with either an increase or decrease in gassing values.

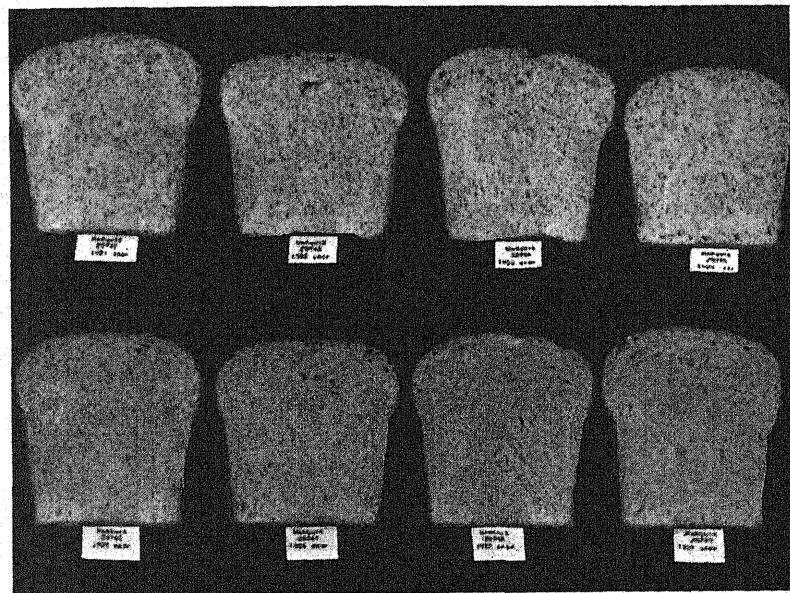

FIG. 1.—Loaves of bread baked in 1938 by the commercial-bromate procedure for Marquis grown in the various years 1921 to 1929.

FIG. 2.—Loaves of bread baked in 1938 by the commerical-bromate procedure for Kanred from the crop years of 1921, 1924, and 1929.

All of the samples produced satisfactory bread. Strangely enough, the Marquis from the 1921 crop averaged highest in loaf volume and scored but slightly less in grain and texture than the 1929 Marquis, which was materially lower in loaf volume.

The 1921 Marquis was, it is true, relatively high in protein, 14.4%; nevertheless, it produced bread superior to that of the 1927 crop with

practically the same protein content. Also the 1921 Kanred produced better bread than either the 1924 or the 1929 crops. Here, again, the protein content of the 1921 crop was relatively high.

Altogether, there is no indication in either the milling or baking data of any material deterioration in quality for bread of any of the samples.

SUMMARY

Milling and baking tests were made with eight samples of Marquis wheat and three samples of Kanred wheat stored at Fort Collins, Colorado, in a dry, unheated room for periods up to 17 years. There was a definite and fairly regular increase in fat acidity with storage, indicating a certain amount of progressive deterioration on storage. Satisfactory flour yields were obtained in all cases and unusual tempering was not required in any case. All lots made satisfactory bread, there being no indications of deterioration in baking quality in any of the samples. The best bread both from Marquis and Kanred was made from the 1921 crop, but the small difference as compared with later crops can probably be attributed to higher protein content. There was no apparent relation between deterioration in viability as shown by germination tests and baking quality.

THE FIXATION AND RELEASE OF APPLIED POTASH ON THREE COASTAL PLAIN SOILS[1]

J. M. Blume and E. R. Purvis[2]

THE role of potassium in the chemical and physico-chemical phenomena of the soil has been the subject of exhaustive research; yet, one of the more practical aspects of the problem has not been entirely clarified. This concerns the fate of the potassium applied to soils in commercial fertilizers. The larger part of the element so added is probably utilized by the current crop; however, a considerable fraction remains in the soil in a water-soluble, replaceable, or fixed form. The controversial issues concern the fraction of the unutilized potassium which enters each of these three forms, and the ease with which it changes from one form to another. In areas where large quantities of commercial fertilizer are used, this unutilized potassium, plus the potassium returned to the soil in plant residues, represents, over a period of years, a considerable investment to the grower. The practical considerations of the problem are apparent for it is important that the grower know what part of this investment is available for future use and what part is lost or becomes a frozen asset. This paper presents a study of the fate of potassium applied to three representative virgin soils of the vegetable-growing area of eastern Virginia.

EXPERIMENTAL PROCEDURE

An Elkton silt loam, a Portsmouth loamy fine sand, and a Sassafras sandy loam were chosen for the study. Various chemical data on the soils selected are presented in Table 1.

Table 1.—*Characteristics of original soils.*

Character	Portsmouth	Sassafras	Elkton
pH	4.1	4.6	5.30
pH after liming	6.1	6.0	7.2
Total nitrogen, %	0.43	0.183	0.095
Organic matter, %	21.6	4.5	1.5
Clay, %	5.0	17.0	9.0
Replaceable Ca, M.E./100 grams soil	2.06	1.45	1.5
Replaceable Mg, M.E./100 grams soil	0.49	0.72	1.01
Replaceable K, M.E./100 grams soil	0.28	0.26	0.11
Exchange capacity, M.E./100 grams soil	27.0	11.1	5.2

The soils were collected from the virgin state, screened, all amendments added, thoroughly mixed, and placed in 2-gallon glazed earthenware urns. Fifty-six urns of each soil were divided into four series according to treatment and method of

[1]Contribution from the Virginia Truck Experiment Station, Norfolk, Va. Credit is given Dr. Jackson B. Hester, formerly of this Station, for assistance in outlining the problem and reading this manuscript, and to the American Potash Institute for supplying the funds which made this study possible. Received for publication August 5, 1939.

[2]Research Fellow and Soil Technologist, respectively.

study as follows: Series A, unlimed and unleached; series B, limed and unleached; series C, unlimed and leached; and series D, limed and leached.

Duplicates in each series received potassium treatments at the rate of 0, 50, 100, 200, 400, 800 and 1,600 pounds per acre of K_2O from commercial muriate of potash (62% K_2O). In addition, each urn received 2 grams of P_2O_5 and 2 grams of N from the sources Ammophos and urea. Hydrated magnesium lime was added to series B and D in amounts calculated to produce a soil reaction near pH 6.0. The reactions obtained are shown in Table 1. Because ot the unexpected high silt and low colloid content, the Elkton soil, through error, was overlimed. The urns were placed in the greenhouse and the moisture content adjusted to one-half the water-holding capacity of the various soils. Constant moisture was maintained throughout the period of the study by weighing and adjusting twice weekly, with the exception of two weekly periods when watering was purposely omitted to permit the soils partly to dry.

Soil samples were drawn from each urn of series A and B at monthly intervals over a period of five months, and from series C and D after leaching at the ends of the first, third, and fifth months. To insure accurate sampling, 10 ¾-inch cores were drawn from each urn and thoroughly mixed. These samples were then subjected to analysis. Twelve and one-half grams of soil were leached with 250 mls. of water and the potassium determined in the leachate. Leaching with water was followed by leaching with 250 mls. of ½ N ammonium chloride solution adjusted to pH 7.0 with dilute ammonium hydroxide, and the replaceable potassium was determined. The fixed potassium was calculated from the amount added less the amount found in the water-soluble and replaceable states.

The urns of series C and D were subjected to monthly leachings with water, sufficient water being added to produce 2 liters of leachate at each leaching. These leachings were subjected to analysis for potassium by the sodium cobaltinitrite method, the method employed for all potassium determinations in this study.

RESULTS FROM UNLEACHED SERIES

The results from the study of series A and B are presented in Tables 2 and 3. It will be noted from Table 2, that in the case of the unlimed soils, only the Portsmouth fixed an appreciable amount of potassium. In this soil, the maximum fixation of potassium in all treatments occurred during the first two months. After the second month, part of this fixed potassium was apparently released, and at the end of the fifth month, the soils receiving the four higher treatments held in the fixed state approximately half as much potassium as was fixed at the end of the first month. There was considerable variation in the amount of potassium fixed within each treatment over the five months' period and there seems to be no consistency in this variation between treatments. It is believed that this inconsistency is significant for reasons which will be discussed later.

The unlimed Sassafras and Elkton soils fixed relatively little potassium at any time during the study, often showing negative fixation, i.e., release of potassium originally held in the fixed state.

Table 3 records the results from the study of the unleached, limed soils. As was expected, liming increased fixation in the Sassafras and Elkton soils. This was especially true in the case of the Elkton, for this soil in the limed condition showed a greater fixing power than

TABLE 2.—*Replaceable and fixed potassium on unlimed soils in M.E. of K per 100 grams of soil.*

	Days*	Pounds K_2O applied per acre						
		0	50	100	200	400	800	1,600
				Portsmouth				
M.E. K applied per 100 grams soil	—	0	0.086	0.173	0.345	0.690	1.380	2.760
Water-soluble plus replaceable K	30	0.310	0.320	0.430	0.510	0.695	1.040	1.810
	60	0.310	0.305	0.325	0.480	0.685	1.155	2.030
	90	0.280	0.280	0.370	0.555	0.905	1.315	2.390
	120	0.320	0.330	0.465	0.625	0.870	1.215	2.235
	150	0.320		0.410	0.615	0.855	1.385	2.285
Fixed K	30		0.076	0.053	0.145	0.305	0.650	1.260
	60		0.091	0.158	0.175	0.315	0.535	1.040
	90		0.086	0.083	0.070	0.065	0.345	0.650
	120		0.076	0.028	0.040	0.140	0.485	0.845
	150			0.083	0.050	0.155	0.315	0.795
				Sassafras				
M.E. K applied per 100 grams soil	—	0	0.063	0.125	0.250	0.500	1.000	2.000
Water-soluble plus replaceable K	30	0.230	0.285	0.350	0.445	0.805	1.050	2.065
	60	0.245	0.255	0.380	0.455	0.685	1.075	1.995
	90	0.225	0.265	0.425	0.425	0.715	1.185	2.085
	120	0.240	0.320	0.410	0.500	0.710	1.370	2.430
	150	0.230	0.285	0.345	0.450	0.710	1.215	2.675
Fixed K	30		0.008	0.005	0.035	−0.075	0.180	0.165
	60		0.053	−0.010	0.040	0.060	0.170	0.250
	90		0.023	−0.075	0.050	0.010	0.040	0.140
	120		−0.017	−0.045	−0.010	0.030	−0.130	−0.190
	150		0.008	0.010	0.030	0.020	0.015	−0.445
				Elkton				
M.E. K applied per 100 grams soil	—	0	0.052	0.104	0.208	0.415	0.830	1.660
Water-soluble plus replaceable K	30	0.095	0.140	0.220	0.295	0.605	0.940	1.875
	60	0.095	0.140	0.210	0.300	0.565	0.860	1.695
	90	0.095	0.155	0.220	0.400	0.560	1.030	1.900
	120	0.125	0.150	0.255	0.375	0.585	0.930	1.980
	150	0.080		0.150	0.300	0.540	0.830	1.880
Fixed K	30		0.007	−0.021	0.008	−0.095	−0.015	−0.120
	60		0.007	−0.011	0.003	−0.055	0.065	0.060
	90		−0.008	−0.021	−0.097	−0.050	−0.105	−0.145
	120		0.027	−0.026	−0.042	−0.045	0.025	−0.195
	150			0.034	−0.012	−0.045	0.080	−0.140

*Number days after application of potash at which sample was taken.

did the Sassafras, the reverse of what was found in the study of the unlimed soils.

Liming apparently had no effect upon the amount of potassium fixed by the Portsmouth soil although it did seem to affect the time of fixation, the greatest fixation occurring at the end of the fourth and

TABLE 3.—*Replaceable and fixed potassium on limed soils in M.E. of K per 100 grams of soil.*

	Days*	Pounds K_2O applied per acre						
		0	50	100	200	400	800	1,600
		Portsmouth						
M.E. K applied per 100 grams soil	—	0	0.086	0.173	0.345	0.690	1.380	2.760
Water-soluble plus replaceable K	30	0.445		0.580	0.695	0.860	1.225	2.135
	60	0.405	0.440	0.525	0.615	0.925	1.255	2.175
	90	0.450	0.465	0.545	0.680	0.945	1.405	2.265
	120	0.440	0.455	0.530	0.680	0.875	1.385	2.085
	150	0.440	0.490	0.550	0.685	0.810	1.255	2.110
Fixed K	30			0.038	0.095	0.275	0.600	1.070
	60		0.051	0.053	0.135	0.170	0.530	0.990
	90		0.071	0.078	0.115	0.195	0.425	0.945
	120		0.071	0.083	0.105	0.255	0.435	1.115
	150		0.036	0.063	0.100	0.320	0.565	1.090
		Sassafras						
M.E. K applied per 100 grams soil	—	0	0.063	0.125	0.250	0.500	1.000	2.000
Water-soluble plus replaceable K	30	0.310	0.390	0.450	0.550	0.830	1.220	2.260
	60	0.330	0.370	0.390	0.485	0.705	1.105	1.885
	90	0.260	0.300	0.400	0.535	0.755	1.215	2.130
	120	0.320	0.365	0.410	0.495	0.735	1.190	1.800
	150	0.265	0.300	0.400	0.470	0.725	1.250	2.300
Fixed K	30		−0.017	0.015	0.010	0.020	0.090	0.050
	60		0.023	0.065	0.095	0.125	0.225	0.445
	90		0.023	−0.015	−0.025	0.005	0.045	0.130
	120		0.018	0.035	0.075	0.085	0.130	0.520
	150		0.028	−0.010	0.045	0.040	0.015	−0.035
		Elkton						
M.E. K applied per 100 grams soil	—	0	0.052	0.104	0.208	0.415	0.830	1.660
Water-soluble plus replaceable K	30	0.140	0.160	0.185	0.240	0.450	0.745	1.540
	60	0.110	0.130	0.165	0.215	0.415	0.790	1.765
	90	0.100	0.170	0.200	0.310	0.420	0.830	1.780
	120	0.130	0.150	0.170	0.250	0.395	0.705	1.450
	150	0.105	0.135	0.170	0.240	0.400	0.755	1.425
Fixed K	30		0.032	0.059	0.108	0.105	0.225	0.260
	60		0.032	0.049	0.103	0.110	0.150	0.005
	90		−0.018	0.004	−0.002	0.095	0.100	−0.020
	120		0.032	0.064	0.088	0.150	0.255	0.340
	150		0.022	0.039	0.073	0.120	0.180	0.340

*Number days after application of potash at which sample was taken.

fifth months instead of at the end of the first and second months as was the case with the unlimed soil.

The data presented in Tables 2 and 3 indicate that the properties of a soil which enable it to fix potassium in an unreplaceable state are dynamic and not constant. With chemical and physical factors con-

stant, this indicates that fixation is brought about by microbiological activity and is temporary in nature. It had been expected that a condition of equilibrium would be reached between the potassium existing in the water-soluble and replaceable conditions and the remainder which had become fixed. This condition of equilibrium was not obtained nor was there any evidence that it was being approached. There is a general correlation between the fixing power of the soils for potassium and their organic matter content and exchange capacity. This correlation holds in the case of the unlimed soils, the Portsmouth fixing the most potassium and the Elkton the least. However, when limed, the Elkton soil fixed practically as much potassium as did the Sassafras. This is probably explained by the difference in pH between the limed Sassafras and Elkton soils. As already mentioned, through error the Elkton was limed to pH 7.2 whereas the Sassafras and Portsmouth soils were limed to approximately pH 6.0. Although this prevents any direct comparison of the fixing capacity of the two soils, the difference in the amounts of potassium actually fixed are too small to be of any consequence.

In the above study, water-soluble potassium was included in the replaceable fraction as has been the common practice in studies of this type. To determine the importance of the water-soluble fractions, soil samples from the three higher treatments of series A and B were subjected to analysis for water-soluble potassium by the method already described. These data are presented in Table 4.

The separation of the water-soluble potassium from the replaceable fraction greatly clarifies the picture in the case of the Portsmouth and Elkton soils. With this separation, the replaceable fraction was found to be practically constant for each treatment throughout the entire period of the study and the amount held in the replaceable state was increased with each successive increment of potash applied. The entire variation in the amount of potassium fixed is reflected in the water-soluble fraction. Apparently the potassium is fixed from the water-soluble condition, the replaceable fraction of the element having no part in the phenomenon. One might assume that a very sensitive state of equilibrium exists in which the potassium fixed from the replaceable state is immediately replaced from the water-soluble fraction. The data presented are not contrary to such an assumption. The replaceable fraction did remain constant even though the water-soluble fraction varied over 100% in several instances. However, such would not be the case if the water-soluble fraction were evenly dispersed throughout the soil mass, for the replaceable fraction is increased as the amount of potassium applied is increased, as is shown in Table 4. To assume a constant replaceable fraction when the other two fractions vary widely is to ignore the conditions of the law of mass action. The percentage base saturation of a soil, with any ion capable of entering the exchange complex, must necessarily increase as the application of the ion in question is increased. To explain a constant replaceable fraction under conditions where the water-soluble fraction varies widely, as was found in this study, one must assume that the potassium released from the fixed state into a water-soluble form was not distributed throughout the soil mass and therefore had no

TABLE 4.—*Relation between water-soluble, replaceable, and fixed potash in M.E. of K per 100 grams of soil.*

K determination	Days*	Portsmouth 400† 0.690‡	Portsmouth 800† 1.380‡	Portsmouth 1,600† 2.760‡	Sassafras 400† 0.500‡	Sassafras 800† 1.000‡	Sassafras 1,600† 2.000‡	Elkton 400† 0.415‡	Elkton 800† 0.830‡	Elkton 1,600† 1.660‡
Unlimed Soil										
Water-soluble K	30	0.210	0.365	0.745	0.245	0.500	1.060	0.385	0.625	1.225
	60	0.305	0.460	0.980	0.310	0.530	1.170	0.320	0.530	1.085
	90	0.425	0.630	1.305	0.395	0.680	1.545	0.310	0.645	1.355
	120	0.445	0.555	1.180	0.435	1.000	2.070	0.335	0.565	1.405
	150	0.430	0.715	1.245	0.400	0.900	2.285	0.365	0.560	1.310
Replaceable K	30	0.485	0.675	1.065	0.560	0.550	1.005	0.220	0.315	0.650
	60	0.380	0.695	1.050	0.375	0.545	0.825	0.245	0.330	0.610
	90	0.480	0.685	1.085	0.320	0.505	0.540	0.250	0.385	0.545
	120	0.425	0.660	1.055	0.275	0.370	0.360	0.250	0.365	0.575
	150	0.425	0.670	1.040	0.310	0.315	0.390	0.175	0.270	0.570
Fixed K	30	0.305	0.650	1.260	−0.075	0.180	0.165	−0.095	−0.015	−0.120
	60	0.315	0.535	1.040	0.060	0.160	0.250	−0.055	0.065	0.060
	90	0.065	0.345	0.650	0.010	0.040	0.140	−0.050	−0.105	−0.145
	120	0.140	0.485	0.845	0.030	−0.130	−0.190	−0.045	0.025	−0.195
	150	0.155	0.315	0.795	0.020	0.015	−0.445	−0.045	0.080	−0.140
Limed Soil										
Water-soluble K	30	0.320	0.500	1.090	0.240	0.370	1.370	0.200	0.450	1.070
	60	0.415	0.550	1.135	0.340	0.585	1.125	0.205	0.435	1.225
	90	0.375	0.715	1.315	0.360	0.685	1.380	0.175	0.450	1.240
	120	0.310	0.630	1.075	0.360	0.625	1.270	0.200	0.375	0.910
	150	0.345	0.635	1.155	0.360	0.740	1.915	0.175	0.425	0.925
Replaceable K	30	0.540	0.725	1.045	0.590	0.850	0.890	0.250	0.295	0.470
	60	0.510	0.705	1.040	0.365	0.520	0.760	0.210	0.355	0.540
	90	0.570	0.690	0.950	0.395	0.530	0.750	0.245	0.380	0.540
	120	0.565	0.755	1.010	0.375	0.565	0.530	0.195	0.330	0.540
	150	0.465	0.620	0.955	0.365	0.510	0.385	0.225	0.330	0.500
Fixed K	30	0.275	0.600	1.080	0.020	0.090	0.050	0.105	0.225	0.260
	60	0.170	0.530	0.990	0.125	0.225	0.445	0.120	0.150	0.005
	90	0.195	0.425	0.945	0.005	0.045	0.130	0.095	0.100	−0.020
	120	0.255	0.435	1.115	0.085	0.130	0.520	0.150	0.255	0.340
	150	0.320	0.565	1.090	0.040	0.015	−0.035	0.120	0.280	0.340

*Number of days after application of potash at which sample was taken.
†Pounds of K_2O applied per acre.
‡M. E. of K applied per 100 grams of soil.

opportunity to enter the exchange complex. If potassium fixation and release were the result of microbiological activity, the existence of potassium in a water-soluble but undispersed state could be accounted for. The dead bodies of microbes might well hold potassium against diffusion in a soil of limited moisture content, yet release this potassium under the treatment employed in the analysis for water-soluble potassium. This possibility of a microbiological factor will be discussed later.

The relationship between the water-soluble, replaceable, and fixed potassium for the 800-pound K_2O treatment on the unlimed Portsmouth soil is graphically illustrated in Fig. 1. The data from all treatments for both the unlimed and limed series of the Portsmouth and Elkton soils give similar curves.

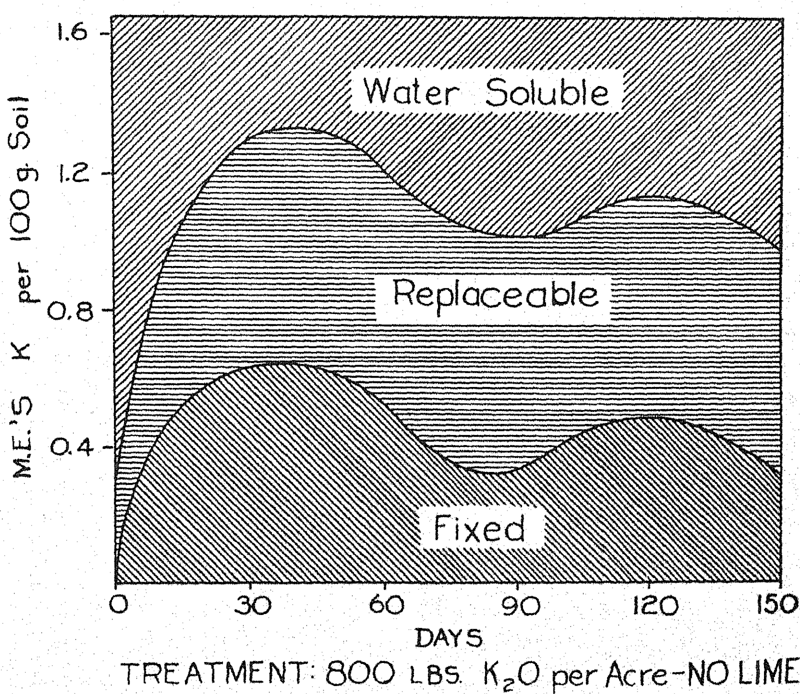

FIG. 1.—Fate of applied potash on Portsmouth soil.

For unexplained reasons the replaceable fraction of potassium did not remain constant in either the limed or unlimed series of the Sassafras soil but tended to decrease with time. The fixed fraction varied widely from month to month but also had a general tendency to decrease, both of these decreases being reflected by an increase in the water-soluble fraction. Apparently the exchange complex of this soil was appreciably altered during the study, possibly by rapid decomposition of the organic fraction.

In all three soils, the amount of potassium held in the replaceable state correlates well with their exchange capacities and organic matter contents.

RESULTS FROM LEACHED SERIES

In this series, the soils were leached monthly with sufficient water to produce 2 liters of leachate and the leachings analyzed for potassium. Soil samples were drawn at the end of the first, third, and fifth months after the urns had been leached. These samples were analyzed for water-soluble and replaceable potassium to determine what effect leaching had on this fraction. The results from this series are presented in Tables 5, 6, and 7.

TABLE 5.—*Percentage of applied potassium leached.*

Pounds of K_2O applied per acre	Portsmouth		Sassafras		Elkton	
	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed
50	27.9	12.8	25.4	0	25.0	3.8
100	26.0	12.7	37.6	10.4	37.5	14.4
200	26.1	11.3	42.0	16.4	36.5	19.2
400	30.0	14.2	34.2	19.2	33.5	19.0
800	26.4	16.9	40.1	30.8	49.4	22.9
1,600	31.9	20.0	41.7	47.0	56.1	36.8

TABLE 6.—*M.E. of replaceable K+water-soluble K per 100 grams of soil, samples taken after monthly leachings.*

Pounds of K_2O applied per acre	Portsmouth			Sassafras			Elkton		
	30 days	90 days	150 days	30 days	90 days	150 days	30 days	90 days	150 days
				Unlimed Soil					
None	0.330	0.090	0.110	0.190	0.180	0.135	0.065	0.035	0.060
50	0.315	0.090	0.190	0.190	0.205	0.195	0.100	0.080	0.090
100	0.315	0.305	0.280	0.250	0.240	0.220	0.140	0.115	0.120
200	0.490	0.390	0.360	0.380	0.385	0.290	0.190	0.165	0.210
400	0.645	0.535	0.530	0.445	0.535	0.390	0.330	0.275	0.270
800	0.935	0.860	0.845	0.805	0.715	0.650	0.595	0.350	0.405
1,600	1.370	1.240	1.125	1.340	1.045	1.015	0.895	0.610	0.640
				Limed Soil					
None	0.345	0.325	0.365	0.225	0.225	0.240	0.145	0.055	0.080
50	0.385	0.350	0.390	0.275	0.235	0.235	0.150	0.080	0.145
100	0.430	0.430	0.480	0.335	0.275	0.295	0.175	0.135	0.160
200	0.540	0.550	0.555	0.400	0.360	0.370	0.230	0.180	0.200
400	0.895	0.770	0.740	0.485	0.505	0.520	0.355	0.270	0.325
800	0.995	1.145	1.060	0.725	0.750	0.690	0.630	0.480	0.560
1,600	1.425	1.665	1.445	1.175	1.155	1.130	1.065	0.835	0.795

It will be noted from Table 5 that from a third to a half of the potassium applied on the unlimed soils was removed by leaching. The percentage figures are strikingly consistent for all treatments in the case of the Portsmouth soil. This indicates that similar percentages of the potash applied in all treatments became water-soluble at one time or another during the five months' period and therefore that the potash was removed on a percentage basis. To a lesser extent, the

same relationship holds with the unlimed Sassafras and Elkton soils. Here, however, there is a tendency for the percentage removal to increase with the increase in amount of potassium applied. Since these soils fixed considerably less potassium than did the Portsmouth, more of the element remained in water solution and, therefore, a higher percentage was leached out.

The limed soils lost less potassium than did the unlimed ones. It is believed that this was due to the granulation of the soil by the lime. A floculated soil would naturally be less thoroughly leached than one in which the organic matter and clay were in a defloculated condition. Evidence of the correctness of this theory is presented in Table 6 where it is seen that the limed soils retained considerably more potassium in the water-soluble and replaceable forms, after leaching, than did the unlimed soils. This was especially true at the end of the five months' period.

Since tap water had been used in leaching the above soils, the experiment was repeated with the Portsmouth soil using rain water for leaching in order to eliminate the possibility of potassium replacement by soluble ions in the tap water. The results obtained were in close agreement with those of Table 5 and for this reason are not included here.

Table 6 presents the results for water-soluble and replaceable potassium obtained by analysis of the soils after the first, third, and fifth leaching. With the exception of the two higher treatments of the unlimed Elkton soil, all three soils in all treatments retained more potassium in the water-soluble and replaceable forms at the end of the fifth leaching than was lost in all five leachings, the limed soils retaining a higher percentage as already mentioned. This indicates the importance of soil structure in the retention of soluble ions against leaching and also suggests that the actual loss of potassium from the soil through leaching is much less than would be expected, although it remains in the soil in a water-soluble form.

TABLE 7.—*M.E. of K fixed per 100 grams of soil at end of a five months' period.**

Pounds of K_2O applied per acre	Portsmouth		Sassafras		Elkton	
	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed
50	−0.018	0.050	−0.013	0.069	0.009	−0.015
100	−0.012	0.036	−0.007	0.057	0.004	0.009
200	0.005	0.116	−0.010	0.079	−0.018	0.048
400	0.043	0.217	0.074	0.124	0.066	0.091
800	0.280	0.451	0.084	0.242	0.075	0.160
1,600	0.863	1.124	0.286	0.295	0.149	0.333
M.E. K leached or available per 100 grams soil of O treatment	0.174	0.431	0.192	0.278	0.084	0.100

*K applied plus [K leached, H_2O-soluble and replaceable of O treatment] less [K leached, H_2O-soluble and replaceable of respective treatments].

The amount of the applied potassium which was not accounted for in the leachings or in the water-soluble and replaceable fractions at

the end of the five months' period must be considered as fixed by the soil. The data for this fraction are presented in Table 7. To arrive at the correct values, the amount of K_2O leached from the "no potash" treatment plus that held in the water-soluble and replaceable states in this treatment at the end of the study, were subtracted from the results of all other treatments. Without this correction, all treatments, with the exception of the two higher ones, would show negative fixation (the release of K_2O originally held in fixed state). Even with the correction, negative fixation occurs in a number of instances and fixation is generally low for all of the lower treatments. It has been shown (Fig. 1) that the fixed and water-soluble fractions vary inversely with one another, while the replaceable fraction remains fairly constant. This being the case, the periodic removal of the water-soluble fraction by leaching would progressively lower the fixed fraction until it disappeared completely. The replaceable fraction would also be lowered as the water-soluble portion was removed. The data of Table 7 support this hypothesis and indicate that all of the applied K_2O would be recovered in the water-soluble form in a comparatively short time.

DISCUSSION

It is generally agreed that under certain conditions soils are able to fix potassium in a non-replaceable form. Volk (8)[3] obtained approximately 100% fixation of applied potassium by alternately wetting and drying the soil, but found that no fixation occurred when the moisture content was maintained near the optimum for plant growth. Hoagland and Martin (4) state that, in some soils, all of the applied potassium may enter the replaceable state, while in other soils considerable amounts of the potassium may be fixed.

Perhaps the most significant fact established in the present study is that the fixation of potassium by a soil is a highly reversible phenomenon. Over a five months' period, the amount of applied potassium held in the fixed state in soils maintained at constant moisture and sampled monthly, varied by as much as 100%. Potassium enters the fixed state, is released, and becomes fixed again in a comparatively short time. This is in agreement with the findings of Abel and Magistad (1), Bray and De Turk (2), and many other investigators. However, the data obtained do not support the theory that potassium fixation and release follow the line of an equilibrium reaction. As previously stated, the variation in the amount of potassium fixed over a five months' period was reflected in an inverse variation in the amount of potassium in the water-soluble form, while the amount of the element held in the replaceable state remained constant after the first month.

Since fixation was greatest in the Portsmouth soil which contained the highest percentage of organic matter, and since the variation in the amount of potassium fixed at various samplings was so great, the possibility of a microbiological activity factor is suggested. It is admitted that the data offer no concrete proof of such a factor other than by inference. However, as shown in Fig. 1, the curve for fixed

[3]Figures in parenthesis refer to "Literature Cited", p. 868.

potassium is similar to growth curves of the soil microflora over a period of time. The direct variation between water-soluble and fixed potassium may also be interpreted as evidence of a microbiological factor, since the soil fungi and bacteria would naturally utilize the water-soluble potassium.

Many investigators attribute to potassium an important part in the base exchange reactions of the soil. Merkle (7) found that long-continued use of muriate of potash on a soil increased the replaceable potassium content and reduced the replaceable calcium content. Magistad (6) states that the response of crops in the field to potash is very definitely correlated with the amount of replaceable potassium present. Lamb (5) came to the opposite conclusion, while Gedroiz (3) questioned the actual existence of replaceable potassium in the soil. The data obtained in this study indicate that a considerable part of the applied potash enters into a replaceable state in the soil and that this replaceable potassium will be hydrolized when the water-soluble fraction is reduced by leaching, as is shown in Table 6. The consistency of the replaceable fractions in the unleached series is therefore an unnatural phenomenon due to the constant moisture content maintained. The moisture present was not sufficient to distribute the potassium released from the fixed state, or to hydrolyze the replaceable potassium as the water-soluble fraction was depleted by fixation. It follows from this reasoning that all of the applied potash would become water soluble readily as the existing water-soluble fraction is reduced through leaching or crop removal. This is in accord with the results shown in Table 7.

From a practical standpoint, the results of this study indicate that there is practically no loss of applied potassium on the Coastal Plain soils of Virginia through chemical fixation. Such fixation as does occur is more beneficial than harmful in that it tends to retain temporarily the element in an unleachable state but eventually releases it into a water-soluble form. During the growing period of the average crop it is likely that practically all of the potassium applied in commercial fertilizer is available to that crop at one time or another. Likewise, practically all of the applied potassium is subject to loss by leaching during the growth of the crop. Work now in progress, however, indicates that actual loss by leaching may not be very great since the potassium leached from the surface zone by heavy rains may be returned by evaporative forces during dry weather. This suggests the feasibility of light side applications of potash after heavy rains to tide the plants over a temporary deficiency of this element.

SUMMARY

A study is reported of the fate of potassium applied at the rates of 50, 100, 200, 400, 800, and 1,600 pounds of K_2O per acre to an Elkton silt loam, a Portsmouth loamy fine sand, and a Sassafras sandy loam. Analyses for water-soluble, replaceable, and fixed potassium were made at monthly intervals over a five months' period on limed, unlimed, leached, and unleached, soils kept under greenhouse conditions.

The amount of potassium fixed in all treatments varied greatly from month to month indicating that the properties of a soil which affect fixation are dynamic in nature. The possibility of microbiological fixation is suggested and supported by evidence of an inverse relationship between water-soluble and fixed potassium.

Under controlled conditions, the amount of potassium held in the replaceable state remained constant over the five months' period in the Portsmouth and Elkton soils, while the fixed fraction varied greatly, the variation being reflected in the water-soluble fraction.

Monthly removal of the water-soluble potassium by leaching greatly reduced the replaceable and fixed fractions of potassium in all soils.

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CHEMICAL COMPOSITION OF DIPLOID AND TETRAPLOID *LOLIUM PERENNE* L.[1]

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SOME chemical differences have been recorded between diploid and tetraploid strains of the same species. According to Sansome and Zilva,[3] tetraploid strains of the tomato were higher than diploid in vitamin C. Randolph and Hand[4] found that tetraploid strains of yellow corn were higher than diploids in carotenoids. A comparison is made here of the composition of diploid with colchicine-induced tetraploid tissue of *Lolium perenne*.

Following treatment of seeds of *Lolium perenne* with colchicine, plants were obtained which were chimeras of diploid and tetraploid tissue. By vegetative reproduction diploid and tetraploid clones have been established from a number of these plants. There is no evidence that colchicine produced in this material any other effects than chromosomal reduplication. In the absence of any other effects the diploid and tetraploid clones from each plant should differ genetically in a quantitative manner only, that is by the tetraploid having double the number of chromosomes and, consequently, twice as many alleles of each gene. Thus, this material affords an opportunity of measuring the effects of chromosomal and genic reduplication on chemical composition without the complication of gene differences.

Chemical analyses have been made of the diploid and tetraploid clones from each of five original seedlings. Cuttings were grown in 10 rows in the greenhouse bed. Each of the five original seedlings were represented by two rows distributed at random and each row contained eight individual cuttings consisting of three to five diploid and three to five tetraploid individuals. At the end of the two months the plants were still in a vegetative condition. They were then harvested (February 3, 1939) and the tops of all diploid plants in one row were composited and the tops of all tetraploids in the same row were also composited in another sample. (The samples averaged 50 grams of green weight.) Thus, from the 10 rows 10 pairs of samples were obtained; each pair consisted of one diploid and one tetraploid sample, both from the same original seedling and both grown in the same row.

The samples were preserved and extracted with hot alcohol. Analyses were made for dry matter, for reducing sugars and sucrose according to the bicarbonate method of Phillips,[5] and for crude fiber, total alcohol-soluble nitrogen to include nitrates, and insoluble nitro-

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[1]Contribution of the U. S. Regional Pasture Research Laboratory, Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, in cooperation with the northeastern states. Received for publication August 11, 1939.

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[3]Biochem. Jour., 27:1935–1941. 1933.

[4]Science, 87:442–443. 1938.

[5]Jour. Biol. Chem., 95:735–742. 1932.

TABLE 1.—*Percentages of dry matter, crude fiber, sugars, and nitrogen in diploid and tetraploid plants of Lolium perenne.*

Plant	Row	Dry matter in percentage of fresh weight		Total alcohol-soluble matter in percentage of dry weight		Crude fiber in percentage of dry weight		Reducing sugars in percentage of dry weight		Sucrose in percentage of dry weight		Total sugars as invert in percentage of dry weight		Insoluble nitrogen in percentage of dry weight		Alcohol-soluble nitrogen in percentage of dry weight		Total nitrogen in percentage of dry weight	
		Diploid	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid
C 116	1	15.8	13.7	29.8	31.2	21.10	21.83	0.38	0.55	1.71	1.92	2.18	2.57	3.73	3.72	1.25	1.33	4.98	5.05
	10	16.5	16.8	31.5	31.9	20.20	20.14	0.34	0.31	2.56	3.28	3.02	3.76	3.69	3.72	1.28	1.03	4.97	4.75
C 58	2	17.0	15.8	30.8	31.5	20.88	21.35	0.47	1.01	2.54	2.50	3.14	3.66	3.58	3.57	1.13	1.04	4.71	4.61
	7	18.4	20.0	32.9	34.2	19.86	18.92	0.85	1.09	4.86	5.49	5.96	6.86	3.33	3.38	1.04	0.89	4.37	4.27
C 217	3	13.5	13.4	32.2	32.3	22.12	22.24	1.61	1.81	2.44	3.13	4.17	5.11	3.24	3.19	1.28	1.20	4.52	4.39
	9	13.8	14.4	32.3	32.4	21.44	21.38	0.93	1.52	1.73	2.28	2.74	3.92	3.52	3.25	1.46	1.34	4.98	4.59
C 101	4	15.2	14.9	30.8	32.4	21.02	20.32	0.60	0.64	2.80	3.24	3.55	4.05	3.53	3.46	—	—	—	—
	6	15.4	16.1	32.3	31.6	20.15	19.76	0.43	0.67	3.63	4.17	4.25	5.07	3.59	3.56	1.34	1.27	4.93	4.83
C 177	5	15.8	15.8	33.4	33.8	19.78	19.83	1.95	2.47	4.11	4.75	6.28	7.47	3.46	3.41	—	—	—	—
	8	16.7	16.9	33.4	36.0	19.61	19.13	1.80	1.61	4.48	4.13	6.51	5.96	3.49	3.40	1.15	1.29	4.64	4.69
Mean		15.81	15.78	31.94	32.73	20.616	20.490	0.936	1.168	3.086	3.489	4.180	4.843	3.516	3.466	1.241	1.174	4.762	4.647
Significance		t=0.93*		t=2.64*		t=0.79*		t=2.86*		t=3.66*		t=4.14*		t=1.79*		t=1.50†		t=2.07†	

*With 9 degrees of freedom values of t for P of 0.05 and P of 0.01 are 2.262 and 3.250, respectively.
†With 7 degrees of freedom the value of t for P of 0.05 is 2.365.

gen. The limited amount of material prevented a more complete analysis.

The results were summarized in Table 1. In the statistical analysis, t was calculated by the pairing method and values of t for P of 0.05 and 0.01 were taken from Fisher's[6] table of t.

The tetraploid plants were higher than the diploid in reducing sugars, sucrose, total sugars, and in the proportion of dry matter that was soluble in 80% alcohol. The t for comparison of reducing sugars and soluble dry matter exceeded the value of t for P of 0.05; for sucrose and total sugars t exceeded the value of t for P of 0.01. Therefore the differences can probably be considered statistically significant. The tetraploids in this study were, in general, lower in both soluble and insoluble nitrogen, but the differences were of such slight magnitude as to have no statistical significance. No consistencies were found in total dry matter and crude fiber.

It may be concluded that under the conditions of the experiments and with the material used, chromosomal and genic reduplication causes an increase in the sugar content of *Lolium perenne*.

[6]Statistical Methods for Research Workers. Edinburgh: Oliver & Boyd. Ed. 6. 1936.

LOSS RESULTING FROM PULLING LEAVES WITH THE TASSELS IN DETASSELING CORN[1]

G. H. Dungan and C. M. Woodworth[2]

SPEEDING up detasseling in the commercial production of hybrid seed corn may sometimes result in the removal of a few of the upper leaves along with the tassel. In order to get some measure of reduction in yield of grain following careless detasseling, an experiment was conducted in which the tassel alone was removed and also in which one to four of the upper leaves were removed along with the tassel.

The corn used was U. S. Hybrid 35 (R4×Hy) (WF9×38-11). A plat consisted of three hills each containing from two to three plants. Each treatment was represented by 14 systematically replicated plats, making a total of 42 hills. Individual plat yields were taken and all data presented are averages of the 14 plats of each treatment.

Detasseling was done just as the tassel appeared above the whorl formed by the upper blades. The tassel only, the tassel with one leaf, and the tassel with two leaves were jerked out while grasping the parts to be removed in one hand and holding the plant below the point of the desired break with the other. Removal of the tassel with three leaves and the tassel with four leaves was done by cutting off the stalk with a knife at the proper place. The amount of plant tissue removed in the respective treatments is shown in Fig. 1.

RESULTS

A summary of the results obtained from the removal of no to four leaves along with the tassels is shown in Table 1.

TABLE 1.—*Influence of removing tassels with different numbers of leaves on yield of corn and weight of kernels, Urbana, Ill., 1938.*

Treatment No.	Part of plant removed when tassel emerged	Number of plants	Average weight of 500 kernels, grams	Average yield of shelled corn per plant	
				Pounds	%
1	Tassel only	106	139.6	0.724±0.0182*	100.0
2	Nothing	113	137.1	0.710±0.0189	98.6
3	Tassel and one leaf	112	130.5	0.660±0.0221	91.7
4	Tassel and two leaves	110	128.9	0.610±0.0216	84.7
5	Tassel and three leaves	107	128.8	0.590±0.0144	81.9
6	Tassel and four leaves	117	124.1	0.510±0.0149	70.8

*Standard error.

Removal of tassel and four leaves reduced the yield of grain almost 30% below that of careful detasseling. When one leaf was removed with the tassel the yield was reduced a little more than 8%. Two leaves pulled with the tassel caused a 15% lowering of yield and three leaves removed with the tassel lowered the yield over 18%.

[1]Contribution from the Department of Agronomy, Illinois Agricultural Experiment Station, Urbana, Ill. Received for publication Aug. 11, 1939.
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FIG. 1.—A typical set of corn tops illustrating, from left to right, the tassel alone, tassel with one leaf, tassel with two leaves, tassel with three leaves, and tassel with four leaves.

The data were studied statistically to determine the probability that the differences between the means of the various treatments were significant. The standard error of the mean of the results for any one treatment was calculated and is recorded in Table 1. Then for a comparison of any two treatments, the difference between the two means was determined and divided by the standard error of the difference. If the quotient thus obtained was as high as 2 or higher, it was considered that the difference between the means being compared was the result of the treatment and not simply due to errors of random sampling. The treatment comparisons are given in Table 2.

TABLE 2.—*Statistical comparisons between treatments.*

Treatments	Difference±standard deviation of the difference	D/S.D. difference
1 and 2	0.014±0.0262	0.5343
1 and 3	0.064±0.0286	2.2377
1 and 4	0.114±0.0282	4.0425
1 and 5	0.134±0.0232	5.7758
1 and 6	0.214±0.0235	9.1063
2 and 3	0.050±0.0290	1.7241
2 and 4	0.100±0.0287	3.4843
2 and 5	0.120±0.0237	5.0632
2 and 6	0.200±0.0240	8.3333
3 and 4	0.050±0.0309	1.6148
3 and 5	0.070±0.0263	2.6615
3 and 6	0.150±0.0266	5.6391
4 and 5	0.020±0.0259	0.7722
4 and 6	0.100±0.0262	3.8167
5 and 6	0.080±0.0207	3.8647

As seen in Table 2, only 4 of the 13 possible comparisons gave a quotient (D/S.D. diff.) of less than 2. These were treatments 1 and 2, 2 and 3, 3 and 4, and 4 and 5. Differences in all other comparisons were statistically significant.

Statistically, therefore, there was no difference between plants not detasseled at all and those from which only the tassel or the tassel and one leaf were removed. Also, there was no difference between the removal of one or two blades with the tassel nor between the removal of two or three blades with the tassel.

The falling off of yield of grain as a consequence of leaves removed from the corn plant is in line with the results of investigations by Hume and Franzke (3),[3] Eldredge (2), and Dungan (1), all of whom found that the severance of corn blades at the time the plants were in the early phase of reproduction caused a more marked reduction of grain yield than the removal of the same number of blades earlier or later in the development of the crop. When leaves are taken off before the tassel appears new leaves will unfold as the plant develops. If the blades are not removed until after the ear has developed to some degree, the plant has had the advantage of some photosynthetic

[3]Figures in parenthesis refer to "Literature Cited", p. 875.

activity of the leaves and therefore produces more grain than if the leaves had been taken off earlier.

Plants from which the tassel was carefully removed produced 1.4% greater yield than non-detasseled plants. Leonard and Kiesselbach (5) obtained an increase in yield amounting to 1.5% as a result of detasseling. These workers also review the publications of others, covering 11 trials, 6 of which showed an increase in yield resulting from detasseling. In three of these, detasseling resulted in a reduction of yield and in one no difference in grain yield occurred. Tests in France (5) revealed that the sugar content of the stalks of detasseled plants was higher than that of non-detasseled stalks.

Isidoro (4), working with flint corn in the Philippine Islands, found as a result of comprehensive tests using ear-to-row planting and mass seed plantings at two different planting dates that detasseling resulted in an increase in grain yield of 10%, a difference which was statistically significant.

That pulling out the tassel with and without leaves had an influence upon grain development is further borne out by the data on weight of 500 kernels (Table 1). The average kernel weights were progressively less, almost exactly paralleling the yield reductions following the various detasseling treatments.

SUMMARY

In the commercial production of hybrid corn, tassels are usually jerked out hurriedly and frequently some of the upper leaves are pulled out with the tassel. An experiment was conducted at the Illinois Agricultural Experiment Station in 1938 to obtain information concerning the loss in grain yield resulting from careless detasseling. It was found that:

1. Pulling one leaf with the tassel in detasseling corn reduced the yield of grain 8.3%; pulling two leaves lowered the yield 15.3%; pulling three leaves lowered the yield 18.1%; and pulling four leaves reduced the yield 29.2%.
2. Detasseling without removing any leaves resulted in a yield increase of 1.4% over that of non-detasseled plants.
3. The weight of 500 kernels was materially reduced by pulling leaves with the tassel.
4. These results emphasize the economic importance of detasseling the ear parent plants in breeding plats carefully so that the minimum amount of injury be inflicted.

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THE EFFECT OF MATURITY AT TIME OF HARVEST ON CERTAIN RESPONSES OF SEED OF CRESTED WHEATGRASS, *AGROPYRON CRISTATUM* (L.) GAERTN.[1]

ELIZABETH MCKAY HERMANN AND WILFORD HERMANN[2]

THE increased use of *Agropyron cristatum* (L.) Gaertn. as a forage crop and for soil erosion control has created a demand for information pertinent to management methods. As many days may elapse between the first and final dates of ripening among plant populations, the grower is confronted with the problem of harvesting at a time when the maximum production of mature seed will be obtained. Premature harvests may result in seed which germinates poorly or contains little reserve food, which delayed harvests may permit shattering of ripened seed and a consequent reduction in yields.

It has been shown by Kiesselbach (5)[3] that seed size is not associated with plant yield in corn, but Kiesselbach and Helm (6) have reported that seed size materially influences plant yield in wheat. Salisbury (12) has discussed the relation between size, strength, and maturity of propagules and ability of the plant to establish itself under conditions of competition. Plants from small, weak, immature propagules are placed at a distinct disadvantage when competing for establishment with plants grown from larger propagules. It seems possible that immature, small seed of *Agropyron cristatum* may have a lessened chance of establishment in competition with the same or other species.

Studies by Hay (2, 3, 4) of the germination of crested wheatgrass have indicated that mature, freshly-harvested seed germinates more readily when held at a temperature below 20° C for part of the germination period, but that dry storage of the seed decreases the need for low-temperature treatment during the germination period.

Seedling emergence of crested wheatgrass when seeded at various depths has been reported by Kirk, Stevenson, and Clarke (7), Love and Hanson (10), and Murphy and Arny (11) whose conclusions were similar. Germination was good in surface plantings if satisfactory moisture conditions were maintained. Percentages of emergence decreased with an increase in depth of planting with the optimum depth being less than 1 inch and preferably ½ inch. Emergence (10) and non-emergence (7) of seedlings from planting depths of greater than 2 inches were both reported, but this variation in results might have been due to differences in soil types (11). The investigations reviewed were apparently made with well-ripened seed.

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[3]Figures in parenthesis refer to "Literature Cited", p. 884.

In order to obtain information which might be useful in determining a favorable cutting date, seed was harvested at several stages of maturity and investigations were made of the quality of the seed obtained. Experiments were planned to determine the relation of maturity of the seed at harvest to the increase and maximum germination with storage, to the time required to complete germination, to the response to prechilling of the seed before germination, to the effect of different temperatures upon germination, and to the apparent amount of reserve food in the endosperm.

PROCEDURE

Spikes of a 3-year-old stand of standard *Agropyron cristatum* grown in 16-foot single rows spaced 2 feet apart in the Washington Agricultural Experiment Station grass nursery were tagged with the date of anther exsertion. Beginning nine days later, when seed was in the premilk stage, 200 spikes were harvested every three days until the seed was in the soft dough stage, after which date harvests were made at six-day intervals until about 50% of the seed had shattered. Harvesting dates extended from the end of June to the first week of August, 1937. Seed was stored in paper bags at room temperature until tested. Germination tests were made between paper towels in a standard germinating chamber. Temperature of the germinating chamber was 20° C ± 2° C, except when otherwise specified.

Four lots of 100 seeds each were used for each test, and percentages of germination were determined by averaging all the lots that fell within the limits of tolerance as outlined by Leggatt (8). Standard errors of the different tests were computed by the machine method as recommended for application to seed testing by Collins (1). Individual errors rather than a generalized error were used because average percentages were occasionally based on fewer than four lots of seed. The standard errors for other phases of the study were determined in accordance with small population formulae of Love (9).

RESULTS AND DISCUSSION

EFFECT OF STORAGE

Germination tests were begun immediately after harvest and every seven days for 11 weeks. After 11 weeks the period between tests was lengthened. Germination was determined for seed of some of the harvests after approximately 525 days of storage (Table 1). As no germination occurred in the seed of the premilk stage through five weeks after harvest, tests were discontinued. None were made of the early milk seed after the eleventh week as all tests to that time were low and no increase had occurred for several weeks. Seed of other degrees of maturity was tested until the supply was exhausted.

Percentages of germination in all tests made immediately after harvest were noticeably low as compared with those of subsequent tests. This was especially marked preceding and through the development of soft dough, where initial tests showed almost no germination. Seed of all stages of maturity increased in percentages of germination after storage, but the length of the storage period required to reach maximum germination was proportionately less as the maturity of the seed increased. Ripe seed attained maximum

TABLE 1.—*Relation of maturity at time of harvest to the increase of germination after storage and the maximum germination of seed of Agropyron cristatum.*

Stage of maturity at harvest	Days after anther exsertion	Number of days of storage between harvesting and testing*																	
		0 %	7 %	14 %	21 %	28 %	35 %	42 %	49 %	56 %	63 %	70 %	77 %	85† %	110† %	165† %	225† %	280† %	525† %
Premilk....	9	0	0	0	0	0	0	—	—	—	—	—	—	—	—	—	—	—	—
Early milk.	12	0	0	1	1	3±1	4±1	5±1	15±2	12±1	11±4	12±1	8±2	—	—	—	—	—	—
Milk......	15	0	1	2±1	9±1	24±2	28±2	22±3	26±1	21±1	23±2	33±4	42±2	45±2	64±3	60±2	—	—	—
Late milk..	18	1	1	11±3	2±1	64±3	63±2	46±2	65±1	73±3	66±2	67±3	58±5	67±2	73±1	65±1	70±2	62±1	64±2
Early dough	21	2±1	38±3	84±3	73±2	64±2	85±2	85±1	84±1	81±3	75±2	87±2	89±1	90±1	88±2	93±1	92±2	84±1	—
Soft dough.	24	8±1	59±2	74±3	82±4	86±2	88±1	86±1	86±2	87±1	83±4	83±1	89±2	76±3	93±1	87±3	86±2	89±1	88±1
Hard dough	30	53±2	63±1	83±2	83±2	87±2	88±1	92±1	90±1	—	94±1	90±2	87±1	93	94±1	95±1	96±1	93±1	—
Ripe.......	36	77±2	78±3	89±1	83±2	85±2	91±2	91±1	92±2	94±1	92±2	95±1	95±1	94±2	95±1	95±1	—	—	—
Slightly shattered	42	73±3	87±1	82±2	78±2	90±1	89±1	84±3	91±2	91±2	91±1	92±1	96±1	93±3	95±1	94±2	95±1	96±1	—
Shattered 50%	48	74±3	78±1	94±1	89±1	90±2	92±1	91±1	95±1	94±1	95±1	93±1	92±2	94±1	95±1	97±1	95±2	96±2	94±1

*Tests were made at 20° C between paper towels, using four lots of 100 seeds each.
†Approximate.

percentages of germination after two weeks of dry storage following harvest.

Maximum percentages of germination increased with greater maturity of the seed through the late milk stage, beyond which differences in stored seed were not significant. Maximum germination up to and including the late milk stage was 70 to 75%, while all seed from later harvests reached maximums of more than 90%.

SPEED OF GERMINATION

Records were made of the number of days required to complete germination. The time required for completion of tests, summarized in Table 1, is shown graphically in Fig. 1 for seed of five different

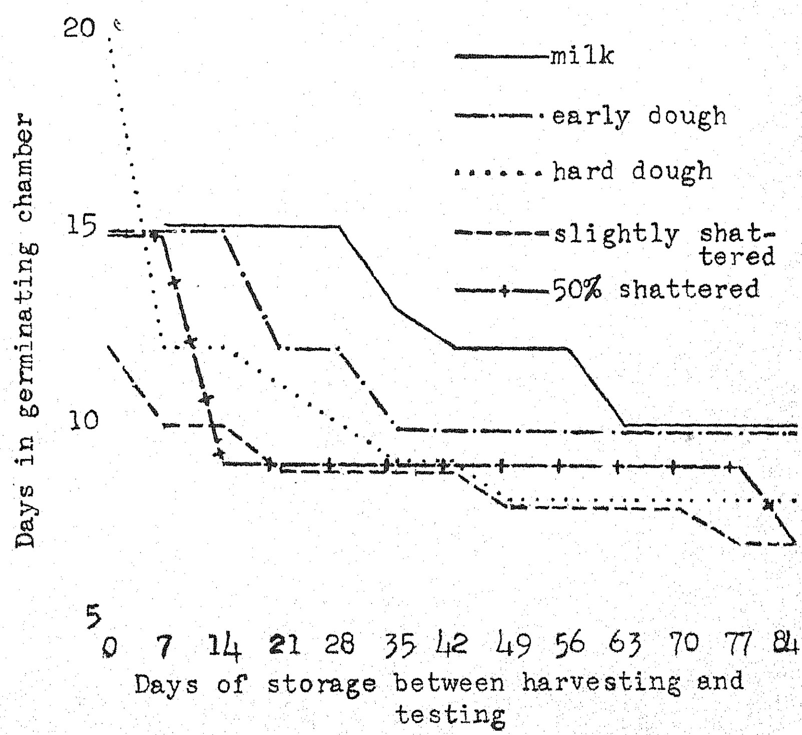

FIG. 1.— Relation between the maturity and the time required for germination of seed of *Agropyron cristatum*.

degrees of maturity. In general, the mature seed germinated more quickly after harvest and required less time than immature seed. Ten days were necessary for seed in the early dough stage, while the more mature seed germinated in seven days after storage for several weeks. Reference to Table 1 shows that seed which had reached hard dough development was the most immature seed to germinate readily when tested immediately after harvest. The hard dough seed required

more time to germinate when tested immediately after harvest than did less mature seed, but this discrepancy is probably explained by the much higher germination of the hard dough seed. Seed which had been harvested after 50% had shattered was slower in germinating than seed which had been harvested earlier. Probably the seed which germinates more quickly also shatters more quickly than less vigorous seed. This would be in accordance with general observations in cereals and corn.

EFFECT OF PRECHILLING UPON GERMINATION

In order to determine the effect of prechilling on germination of seed of different maturity, tests were made in which the seed was placed at 8° to 10° C in dampened towels for seven days before being germinated at 20° C. The prechilling tests were conducted immediately after harvest and again five weeks later. The germination of seed which had been prechilled was compared with the germination of seed in which the test was started at the time the prechilling was begun and with that in which the test was started simultaneously with the transfer of the prechilled seed to 20° C (Table 2).

TABLE 2.—*Relation between the maturity and the response to prechilling before germination of seed of Agropyron cristatum.*

Stage of maturity at harvest	Number of days between harvesting and testing*					
	0	7		35	42	
	%	Dry stored† %	Pre-chilled‡ %	Dry stored %	Dry stored† %	Pre-chilled‡ %
Premilk	0	0	0	0	—	—
Early milk	0	0	0	4±1	5±1	19±2
Milk	0	1	0	28±2	22±3	27±1
Late milk	1	1	0	63±2	46±2	72±2
Early dough	2±1	38±3	7±2	85±2	85±1	85±2
Soft dough	3±1	59±2	4±1	88±1	86±1	86±2
Hard dough	53±2	63±1	83±1	88±2	92±1	94±1
Ripe	77±2	87±3	92±1	91±2	91±1	95±1
Slightly shattered	73±3	87±1	91±2	89±1	84±3	93±1
Shattered 50%	74±3	78±1	91±1	92±1	91±1	94±2

*Tests were made at 20° C between paper towels, using four lots of 100 seeds each.
†Stored dry at room temperature instead of being prechilled.
‡Held at 8° to 10° C between damp towels for seven days.

Chilling produced varying results with seed of different maturity. Through the late milk stage, germination did not occur in either chilled or unchilled seed during the first two weeks after harvest. In the earlier tests seed in the early dough and soft dough development was definitely retarded by chilling, as germination was much higher in seed which had been stored dry for one week than in seed which was chilled for a similar period. Seed in the hard dough stage showed a considerable increase in germination when chilled for seven days as compared with the germination when stored dry for one week. However, reference to Table 1 shows that a second week of dry storage resulted in germination comparable to that in the chilled seed. Ripe

and slightly shattered seed showed no significant differences between chilled seed and seed which had been stored for one week, but the seed which had shattered 50% germinated better after prechilling than after storage for one week, but not better than after two weeks of storage. Hay (2, 3, 4) has reported that prechilling increased germination in freshly harvested Montana-grown crested wheatgrass seed of 1935, which is in accordance with the results reported here for seed of the hard dough and to a lesser extent for seed of more advanced stages.

After storage for five weeks, only seed in the early milk stage displayed a consistently favorable response to prechilling. Seed of certain other harvests showed no increased percentage of germination as a result of prechilling, while increases in the remainder were of only slight significance.

TEMPERATURE OF GERMINATION

Tests were made of seed harvested at four degrees of maturity to study the differential response to different temperatures during germination. Seed used in the study had been stored for 225 days. The seed was tested at alternating temperatures of 10° C for 16 hours and 20° C for 8 hours daily, and of 20° C for 16 hours and 30° C for 8 hours daily, and at constant temperatures of 10° C, 15° C, 20° C, and 30° C.

Because seed of *Agropyron cristatum* is often subjected to low temperatures under field conditions, another test was made in which the seed was held at 0° to 2° C for one week before being germinated at 20° C (Table 3).

TABLE 3.—*Relation between the maturity and the germination at different temperatures of seed of Agropyron cristatum.*

Stages of maturity at harvest	Germination* at given temperatures, %						
	Prechilled at 0°–2° C for 7 days, constant 20° C	Not prechilled					
		Constant				Alternating	
		10° C	15° C	20° C	30° C	10°–20° C	20°–30° C
Early dough.......	15±2	88±1	90±2	84±1	89±1	90±1	88±1
Hard dough.......	74±2	92±1	95±1	94±1	94±1	94±1	96±1
Slightly shattered..	90±2	95±1	96±1	92±2	95±1	93±1	91±1
Shattered 50%....	82±3	90±2	95±1	92±2	89±2	89±2	89±2

*Tests were made between paper towels in four lots of 100 seeds.

Alternation of temperatures was not effective in changing germination in any of the material tested. Chilling of the seed at the beginning of germination caused a reduction of nearly 70% in germination of the early dough seed and of nearly 20% in the hard dough seed. Other differences which resulted were of too little significance to be conclusive. Slight decreases in germination at 20° C after chilling, at 10° C, and at 30° C were shown by the most mature seed. Seed which had been harvested when slightly shattered germinated better than seed of any other harvest, and equally well at different temperatures.

RESERVE FOOD IN ENDOSPERM

To obtain an indication of the amount of reserve food in the endosperm of the seeds, observations were made of the seed weights, of the emergence of seedlings from different depths of planting, and of the heights reached by seedlings grown in darkness (Table 4).

TABLE 4.—*Relation between the maturity and the apparent amount of reserve food in the endosperm of seed of Agropyron cristatum.*

Stages of maturity at harvest	Average weight per 100 seeds, grams	Percentages of emergence from given depths					Heights of seedlings grown in darkness, cm
		½ in.	1 in.	1½ in.	2 in.	3 in.	
Early milk..	————	4±1	8±4	0	0	0	36±5
Milk.......	.1688±.0004	17±1	10±1	2±1	1	0	45±5
Late milk...	.1898±.0003	14±1	15±1	1	0	0	60±5
Early dough	.2426±.0018	43±1	46±1	3±1	2±1	0	83±8
Soft dough..	.2506±.0019	46±1	37±5	10±1	3±1	0	75±4
Hard dough	.2949±.0034	58±4	60±1	32±4	18±5	0	109±5
Ripe.......	.3006±.0010	71±5	66±1	35±3	18±6	1	106±5
Slightly shattered	.3047±.0028	82±1	76±2	43±8	22±4	0	113±4

Between six and seven months after harvest, seed of each stage of maturity was weighed in four lots of 100 seeds each and the average weights per 100 seeds were determined.

Duplicate lots of 66 seeds each for each harvest were planted in Palouse silt loam in greenhouse flats at depths of ½, 1, 1½, 2, and 3 inches and the number of emerging seedlings counted for each depth. Observations were made of the lengths of the coleoptiles and of the color and general vigor of emergent seedlings. Non-emergent seedlings were uncovered and examined to determine the reason for failure to emerge.

Fifty seeds of each harvest were planted at ¼-inch depths in Palouse silt loam and were grown in darkness until deterioration of the seedlings became apparent, when the heights of the seedlings were measured.

Corresponding differences appeared in seed weights, emergence in soil, and heights of seedlings grown in darkness. Weights per 100 seeds increased with maturity for seed of each harvest through the hard dough, beyond which only increases of slight significance occurred.

In all cases emergence was better from the ½- and 1-inch depths than from deeper plantings and failed or was negligible from the 3-inch depth. Lack of vigor of seed up to and including that of the late milk development was shown by general failure of emergence at more than 1 inch and by low emergence percentages at the shallow depths. Emergence was considerably greater from ½- and 1-inch plantings for the early dough and soft dough stages, but was very small from depths of 1½ inches or more. In seed of the hard dough and more mature stages, as compared with less mature seed, greater vigor was shown by the better emergence from the deeper plantings. Little difference is shown in emergence at 2 inches of hard dough

seed, ripe seed, and slightly shattered seed, but shallow plantings showed more variation. Emergence of the more mature seed at the various depths of planting is in accord with the results of Kirk, Stevenson, and Clarke (7), Love and Hanson (10), and Murphy and Arny (11) who worked with mature seed. Seedlings produced from seeds of the earlier harvests were observed to be distinctly weak and chlorotic when compared with seedlings developed from seeds of the later harvests.

In all cases of non-emergence, germination was as good as in laboratory tests, but the seedlings did not appear because the coleoptiles failed to elongate sufficiently to break the soil surface. When the coleoptiles stopped elongating, they were ruptured by the plumules which spread out under the surface of the soil. Kirk, Stevenson, and Clarke (7) have likewise reported this response in crested wheatgrass.

Apparently the maximum length of the coleoptile is closely associated with the endosperm reserve of the seed for non-emergence of seed of all degrees of maturity for which tests were made was due to lack of coleoptile elongation rather than lack of germination.

When planted at a ¼-inch depth and grown in complete darkness, the seed germinated about as well as between paper towels. Chlorophyll failed to develop and 20 days after planting deterioration of the seedlings became evident. Final heights of the seedlings increased with maturity of the seed through that in the hard dough. Among seed of the hard dough stage and seed of subsequent harvests there were no significant differences in final heights.

CONCLUSIONS

These investigations indicate that seed of *Agropyron cristatum* harvested in the early dough stage of development may have high viability but that vigorous plants probably can not be expected from seed harvested earlier than in the hard dough stage. At favorable temperatures, germination and vigor of hard dough seed is as good as in more mature seed, but a decrease of germination in hard dough seed chilled for a week indicated that this may be slightly less hardy than more mature seed.

SUMMARY

Spikes of a 3-year-old stand of *Agropyron cristatum* were tagged with the date of anther exsertion and harvested at regular intervals from nine days after anther exsertion until the seed was 50% shattered.

Germination tests were made at 20° C of seed from each harvest immediately after harvesting, at weekly intervals for 11 weeks, and at irregular intervals thereafter up to 525 days. These tests showed that seed of *Agropyron cristatum* did not germinate well immediately after harvest, but that storage of the seed resulted in increased and accelerated germination. The storage period necessary for good germination was shorter in more mature seed. Both the germination immediately after harvest and the maximum germination after storage were higher as maturity increased. Likewise, the amount of time required for the completion of germination decreased with both

maturing and storage of the seed. Seed in the early dough stage reached a maximum germination nearly equal to that of later stages, but the storage period necessary to reach a maximum and the time required to complete germination were both longer.

Germination tests were made in which seed from each harvest was chilled at 8° to 10° C for one week before being germinated at 20° C. In seed which had been stored for five weeks, the low temperature had very little effect. In seed tested immediately after harvest, low temperatures reduced germination in seed up to and including that in the soft dough development, stimulated germination in seed in the hard dough, and had little more effect than a week of dry storage in more mature seed except in that which was heavily shattered.

Seed of each of several degrees of maturity which had been stored several months was germinated at several different temperatures, and at a favorable temperature after being chilled for seven days. Except for less mature seed which showed decreased germination following a week at very low temperatures, differences in germination of only slight significance were obtained at the different temperatures.

Observations were made of seed weights, of percentages of emergence from different depths of planting, and of heights of seedlings grown in darkness. These increased with greater maturity of the seed, but the increases were not large in seed harvested after reaching the hard dough stage. Best depth of planting appeared to be less than 1 inch, while only the more mature seeds produced emergent seedlings at the 2-inch depth and very little emergence occurred from 3 inches.

The investigations indicated that seed of high viability may be obtained by harvesting as soon as the early dough development, but that vigorous seedlings could not be expected from seed harvested earlier than when in the hard dough stage.

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HEAT CONDUCTIVITY AS AN INDEX OF SOIL MOISTURE[1]

BYRON SHAW AND L. D. BAVER[2]

ELECTRICAL conductivity methods of measuring soil moisture have failed because the conductivity of the soil at a given moisture content vaires greatly with changes in the salt concentration of the soil solution. A successful method of measuring changes in soil moisture will necessarily be one that uses some property of the soil and the soil solution that is not influenced by changes in the salt content. Heat conductivity should be a property of such a system which would not be materially affected by the presence of ions in solution, since rather large changes in the concentration of a dilute salt solution have very little influence on the thermal conductivity.

The heat conductivity of a dry porous medium, such as soil, must of necessity be low, since the solid materials make only point contacts. The area for continuous heat flow through soil materials is very small. A negligible amount of the heat is conducted by the air in the pores, since air is a much poorer conductor than the soil solids. As water is added to the soil, the area through which heat can flow will increase tremendously since the water will form wedges around the points of contact. Water is not as good a conductor of heat as the solid soil material, but it is a far better conductor than air. Thus, it is to be expected that the heat conductivity of a soil will increase with its moisture content. The investigations of Patten[3] bear out this conclusion.

In view of the above considerations, an investigation of the heat conductivity of soil was undertaken with the following objectives: (1) To find a relatively simple method of measuring the changes in heat conductivity of a soil at various moisture contents; (2) to study the relationship between heat conductivity and moisture content; (3) to verify the conclusion that variations in the concentration of salts in the soil solution will not affect the conductivity of heat, and (4) to study the possibilities of using heat conductivity as an index of the changing moisture conditions of the soil *in situ*.

The instrument devised for measuring the changes in heat conductivity of a soil at varying moisture contents is shown diagrammatically in Fig. 1. It is an adaptation of the Wheatstone bridge. R_1 is a fixed manganin resistance of about 7 ohms; R_2 is a variable resistance box; B and C are the other two arms of the bridge. They consist of equiresistant coils (about 8 ohms) of No. 40 enameled copper wire wound on 6-mm glass tubing. Leads of large copper wire go through the walls of the glass tubing and are soldered to the fine wire. The tubes are sealed water tight. These coils are held stationary by tightly fitting water proof plugs in the bottom of ¾-inch circular chambers drilled through a cylindrical brass block 3 inches in diameter and 3 inches high. The chambers are closed at the top by rubber stoppers. The brass block is used to maintain equal external condi-

[1]Contribution from the Department of Agronomy, Ohio State University, Columbus, Ohio. Received for publication August 21, 1939.

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[3]PATTEN, H. E. Heat transference in soils. U. S. D. A. Bur. Soils Bul. 59.

tions for both coils and thus to eliminate the necessity of a constant room temperature. The chamber containing coil C is filled with oven-dry soil and the other chamber is filled with soil differing from that in the first only in moisture content. The brass block is tapped 50 times with a hammer to insure a packing of the soil in the chambers that can be duplicated, and also to establish intimate contact with the coils. The bridge is first balanced with dry soil in each chamber. The balance is obtained by varying R_2 until the galvanometer shows no deflection. The total current through the bridge is kept constant at 0.4 ampere.

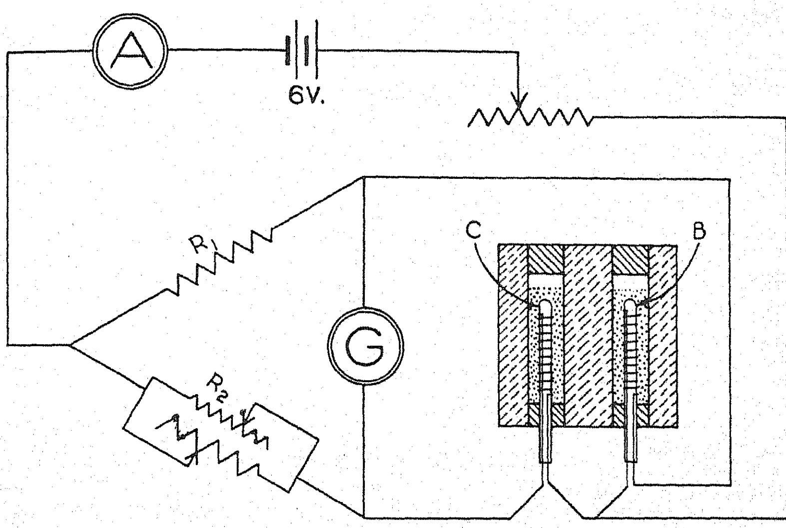

FIG. 1.—Heat conductivity apparatus.

Since the resistance of a copper wire increases with its temperature, the resistances of coils B and C are dependent upon the conductivity of the soil surrounding them. If the heat conductivity of the soil in each chamber is the same, the bridge will remain balanced in spite of the fact the temperature of both coils is continually rising. The resistances of R_1 and R_2 are not affected by temperature changes. Since the copper coils are equally resistant to the flow of electricity they gain heat at the same rate, and inasmuch as the heat conductivities of the materials surrounding the coils are equal, they also lose heat at the same rate. Thus, the temperatures of the two coils remain equal and so it follows that their resistances also stay equal. When the temperature of the coils rises to the point that heat is lost as fast as it is gained, the temperature rise stops.

It can be seen that if the soils in the two chambers have different heat conductivities, the final equilibrium temperatures of the coils will be different. The coil in the material of lowest heat conductivity will have the highest temperature and also the highest resistance. In order for the bridge to be put in balance it is necessary to change the value of R_2. This change from the original value reflects the difference

between the resistances of B and C and, since these resistances are determined by the temperature of the coils, the change is also a measure of the difference between the heat conductivities of the materials in the two chambers. It is not necessary to keep the current flowing through the bridge until the equilibrium condition is reached so long as some standard procedure is adopted for all determinations. If the bridge is balanced with dry soil in each chamber it will still be in balance, as long as no current flows, regardless of the moisture content of the soil in the chamber containing coil B. When the current is turned on the bridge is immediately thrown out of balance due to the unequal rates of temperature rise in the two coils. The maximum displacement from the balance occurs at the time the equilibrium temperatures are reached, but the displacement obtained at an arbitrary time after the current is turned on is equally as representative of the heat conductivities of the soils in the two chambers as is the displacement at equilibrium. An advantage in using a short time interval comes from the fact that in the chamber containing the moist soil, the moisture begins to move away from the coil as soon as the element begins to heat up. Approximately 10 calories of heat are developed at the coil in 2 minutes. This amount of heat is not large enough to cause any appreciable moisture movement since it causes only a very small increase in the temperature of the coil. Readings can be duplicated in from 10 to 15 minutes, or at such time as the coils have again cooled down to equal temperatures.

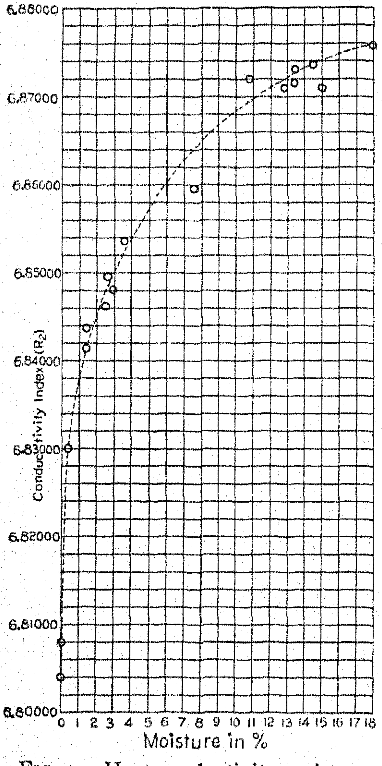

FIG. 2.—Heat conductivity-moisture curve for quartz sand.

The sensitivity of the instrument is very nearly proportional to the cube of the current flowing through the bridge. It is very important, therefore, to keep the current constant during the course of a determination. In a series of measurements in which moisture content is to be the only variable it is important to have the same packing of the soil around the element in each case. This is not easily achieved since the chamber containing the moist soil must be refilled for each different moisture content. The procedure followed consists in using a weight of soil in the moist chamber which contains an amount of oven dry soil equivalent to that in the dry chamber. The

brass block is then tapped 50 times with a hammer. This tapping compacts the soil and makes the volumes very nearly equal. Moist soils have a tendency to occlude air as well as to swell. These factors complicate the packing problem to such a degree that it is not possible to obtain the same compactness in every instance. As a general rule the samples of higher moisture content were packed more loosely.

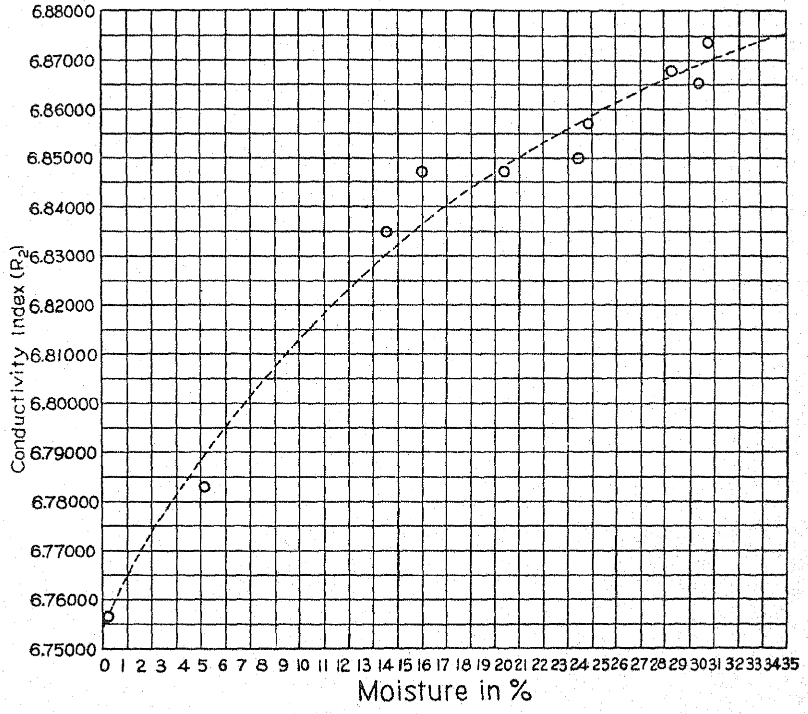

FIG. 3.—Heat conductivity-moisture curve for Davidson clay.

In order to study the relationship between heat conductivity and moisture content in different soil systems, a series of sand and clay were prepared with moisture contents ranging from oven dry to approximate saturation. In the preparation a large sample of soil was wetted to saturation and spread in a thin layer exposed to the air. As drying progressed, portions of about 100 grams were taken at intervals sufficiently long to insure different moisture contents. These were placed in air-tight containers and vigorously shaken every day for a period of two weeks. At this time the moisture distribution was very nearly uniform. Two samples were taken from a container at the time a heat conductivity determination was to be made. One was placed in the moist chamber of the apparatus and the other was used to determine the moisture content. During the filling of the apparatus both samples were exposed to the air for equal times. After the chamber was filled and stoppered, it was allowed to stand 30 minutes be-

fore a reading was taken. In this time interval the soil came into temperature equilibrium with the brass block. Readings were taken 2 minutes after the current was turned on.

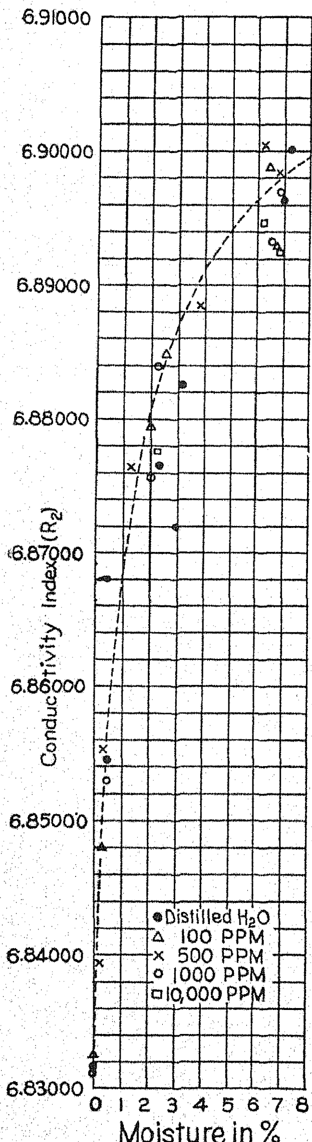

FIG. 4.—Heat conductivity-moisture curve for sand-salt system.

The relationship existing between the indicating resistance (R_2) and moisture content for the quartz sand series is shown in Fig. 2. The steepness of the curve in the low moisture range shows the rapidity with which heat conductivity increases with moisture. This is a natural expectation. In the dry state the sand grains make only relatively few paths of point size cross section for heat flow through the system. Since sand is able to hold only a very slight amount of hygroscopic water, the added water takes the form of wedges around the points of contact. The effective area through which heat can flow is increased tremendously with only small additions of water. As the pores fill with water the effective area is further increased, but the rate of increase becomes less rapid. It is evident that the portion of the curve showing greatest sensitivity extends from zero moisture to above field capacity.

A curve connecting the values of R_2 plotted against moisture content for the Davidson clay series is shown in Fig. 3. The curve does not show the initial rapid rise that was in evidence with sand. This can be explained on the basis of particle size and associated properties. Clay affords many more paths for heat flow in the dry state than sand. Since clay holds a relatively large amount of hygroscopic water, the first additions of water are not as effective in increasing the area through which heat can flow as they were with the sand. The water wedges are built up gradually and this leads to a gradual increase in heat conductivity. The greater variety of pore sizes and greater total pore space in clay lead to a more gradual increase in heat conductivity and also to a greater difference between the conductivity of dry and saturated soil.

Having established the fact that heat conductivity does give an index

of the moisture content of the soil, it is essential to know if the salt concentration of the soil solution affects the results. Five series of quartz sand were prepared having different concentrations of salt in the soil solution. Uniformly distributed moisture was obtained by the method described above. The first series was wetted with distilled water, the second with water containing 100 p.p.m. NaCl, the third with water containing 500 p.p.m. NaCl, the fourth with water containing 1,000 p.p.m. NaCl, and the fifth with water containing 10,000 p.p.m. NaCl. This range extends beyond the limits of salt content found in ordinary soils. The effect of the different concentrations of salt on the conductivity of heat is shown graphically in Fig. 4. While there is considerable scattering of the points from the smooth curve, the variations can in no way be correlated with salt content. The curve drawn fits the data obtained from one series equally as well as the data from any other. The scatter of points is due largely to variations in packing and variations in current. The changes in surface tension associated with differences in salt content increase the difficulty of obtaining the same degree of packing in the wet systems. It appears safe to conclude that changing salt concentrations in the soil solution will not materially affect the heat conductivity at a particular moisture content.

CONCLUSION

The results of these studies point out that the first three objectives of this investigation have been achieved, namely, (1) it has been possible to devise an apparatus for measuring changes in the heat conductivity of a soil at various moisture contents; (2) it has been established that heat conductivity gives a reliable index of the moisture content of the soil; and (3) it has been shown that changes in salt concentration of the soil solution do not materially affect the heat conductivity of the soil.

Work is now in progress to achieve the fourth objective, that is, to adapt the principle of heat conductivity to measuring the moisture of the soil *in situ*. The results of this phase of the investigation will be discussed in a later paper.

EFFECT OF REMOVING DIFFERENT PROPORTIONS OF FOLIAGE ON CONTRASTING STRAINS OF KENTUCKY BLUEGRASS, *POA PRATENSIS* L.[1]

A. O. KUHN AND W. B. KEMP[2]

THERE are many species and strains of grass existing in pastures. It has been shown that strains within a species may vary widely in their morphological characteristics such as height of growth. The effect of height of clipping on various grasses has been studied, but there is no evidence that an attempt has been made to compare various strains of a species when an equal proportion of foliage is removed from all plants.

Investigators (2, 3, 6, 8, 10)[3] have shown that different species react differently to variations in intensity of clipping. In general, investigations (1, 2, 4, 5, 7, 9, 11) into the production of forage by Kentucky bluegrass have shown that the amount of growth below the surface of the ground and the total weight of top growth tend to vary inversely with the frequency and intensity of defoliation.

This paper deals with a comparison between one strain of Kentucky bluegrass which is tall-growing and another which is unusually low-growing, when like proportions of foliage are removed from each.

METHODS

Two strains of Kentucky bluegrass from the Maryland Experiment Station selections were used in this experiment. They were designated as strain 10–3 and strain 12–4. Strain 10–3 came originally from a field where bluegrass had grown for at least 50 years under conditions of little grazing. It is a tall-growing plant (Fig. 1). Strain 12–4 was obtained originally from an alley on the Maryland Experiment Station farm. The alley had been kept closely clipped and subjected to heavy traffic throughout the summer months. This strain is an extremely low-growing type. These strains had been maintained in the grass gardens at College Park under uniform soil conditions for three years prior to their use in the experiment herein reported.

Thirty plants of each strain were taken from among small, uniform, rooted rhizomes and potted in the greenhouse in February. These pots were 7 inches in diameter and 5½ inches deep and contained a sandy loam soil. When the plants had become established in the greenhouse, the pots containing the 24 most uniform plants of each type were selected and placed in the open on a table which was constructed as a watertight basin in order that water might be supplied to the pots. The plants remained on this table throughout the experiment. There were five cutting treatments used, each of which was replicated four times. The clipping point in each type of treatment was none, mid-blade, 1-inch beyond ligule, at ligule, and below ligule.

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[3]Figures in parenthesis refer to "Literature Cited", p. 895.

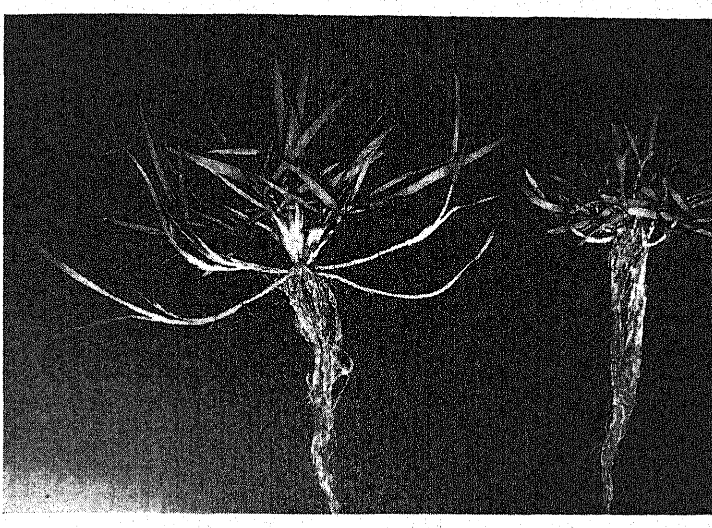

FIG. 1.—Appearance of comparable young plants of contrasting strains of Kentucky bluegrass. *Left*, strain 10–3; *right*, strain 12–4.

Each individual blade of each plant was clipped separately to insure uniform proportionate removals. Clippings were made at two-week intervals beginning April 28. All of the seed and seed stalks were removed on June 15. All of the clippings obtained during the season and the entire plants remaining at the end of the treatments were placed in an oven at 100° F for one week, before weighing. The average height that each removal of clippings actually constituted was determined by a number of measurements of the tops remaining after clippings were made.

EXPERIMENTAL RESULTS

When the same proportions of foliage were removed from each of the two contrasting strains of Kentucky bluegrass, the tall-growing and the short-growing one, increase in severity of defoliation caused a similar and highly significant decrease in the production of roots, rhizomes, and tops (Table 1). The weight of clippings obtained during the season also decreased equally on the two strains with increase in severity of defoliation.

When the comparison between the two strains was based on comparable heights of clipping rather than comparable proportion removed from the plant, there were striking differences between them (Table 2). A mean height of 1.40 inches resulted when strain 10–3, the tall-growing one, was clipped just above the ligule, while a comparable height of 1.60 inches resulted when strain 12–4, the short-growing one, was left unclipped. At these heights of top growth remaining on the plant after clipping, strain 12–4 produced approximately one and a half times as much weight of tops, more than five times as much weight of roots, and more than eight times as much weight of rhizomes as strain 10–3.

TABLE 1.—*Effect of severity of clipping on weight of plant material produced by contrasting strains of Kentucky bluegrass, 1938.*

Clipping point on blade	Mean height after clipping, inches	Production in grams			
		Roots	Rhizomes	Forage	Total
Strain 10-3 (Tall-growing)					
None	3.92	67.1	27.0	69.84	163.94
Mid-blade	2.27	31.8	20.4	64.59	116.79
Inch beyond ligule	2.05	26.1	11.2	49.32	86.62
At ligule	1.40	8.84	4.85	38.77	52.49
Below ligule	1.07	6.84	3.47	35.21	45.52
Strain 12-4 (Low-growing)					
None	1.60	49.2	39.3	53.50	142.00
Inch beyond ligule*	1.17	27.0	27.3	51.09	105.39
Mid-blade*	0.90	21.9	13.0	51.42	86.32
At ligule	0.40	9.70	5.68	38.11	53.49
Below ligule	0.20	5.74	2.50	27.52	35.76

*Treatments reversed because clipping at mid-blade was less than 1 inch from ligule.

TABLE 2.—*The responses of two contrasting strains of Kentucky bluegrass to comparable heights of clipping.*

Strain 10-3		Strain 12-4	
Height, inches	Weight, grams	Height, inches	Weight, grams
Production of Tops*			
1.40	38.77	1.60	53.50
1.07	35.21	0.90	51.42
Production of Roots			
1.40	8.84	1.60	49.20
1.07	6.84	0.90	21.90
Production of Rhizomes			
1.40	4.85	1.60	39.30
1.07	3.47	0.90	13.00

*Includes both harvested material and top growth remaining when plants were removed from soil.

When strain 10–3 was clipped just below the ligule a mean height of 1.07 inches resulted while clipping strain 12–4 so as to remove half of the blade resulted in a comparable height of 0.90 inch. At these heights of top growth remaining after clipping, strain 12–4 produced nearly twice as much weight of tops, three times as much weight of roots, and nearly four times as much weight of rhizomes as strain 10–3.

SUMMARY AND CONCLUSIONS

Two strains of Kentucky bluegrass of contrasting habit with respect to height of growth were compared when like proportions of foliage were removed from each. Increase in severity of defoliation caused a similar and highly significant decrease in the production of roots, rhizomes, and tops.

When comparisons between the two strains were based on comparable height of clipping rather than comparable proportions of the foliage removed, the short-growing strain when clipped either at approximately 1½ inches or at 1 inch produced strikingly more tops, roots, and rhizomes than the tall-growing one.

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NOTES

LONG-TIME STORAGE OF WINTER WHEAT

MANY investigations have been carried on to determine what factors enter into the successful long-time storage of wheat on farms. There has also been much discussion as to the length of time wheat can be stored and still remain viable or usable for milling purposes. The opportunity to secure some information on these questions became available in July, 1938, when a local elevator at Norcature, Kans., purchased 800 bushels of hard winter wheat of the Turkey variety from a crop harvested in 1927 and which had been stored in a farm steel bin for 11 years. The writer secured a sample for milling and baking determinations and also interviewed the grower.

The wheat had been grown by L. P. Montgomery, Clayton, Kans., in 1927 on land that had produced corn in 1926. The 800 bushels were combined when the weather was dry and hot and stored immediately in a 1,000-bushel steel bin. The bin was of tight construction except for a ventilator running from the outside along the floor to a center vertical perforated 6-inch tube having an outlet 10 inches above the top of the bin. The moisture content of the wheat at the time it was stored was not known, but the conditions under which it was combined would indicate that it was well below 12%. When sold in 1938 the moisture content was about 11%.

The wheat was never turned, ventilated, or moved in any manner, and at no time during the 11 years in storage did it show signs of heating. The wheat was never fumigated, but when removed from the bin in 1938 it showed no trace of any damage from insects or other causes. The grain contained traces of yellow berry and, in the main, was of good luster and almost free from cracked kernels. A sample of the 11-year-old wheat sown the fall of 1938 at the Fort Hays Experiment Station produced a stand equal to that from new-grown seed of the same variety. Seed planted in soil in the greenhouse germinated 53%.

The rainfall and temperatures fluctuated very widely during the period from 1927 to 1938. For instance, the seasonal rainfall at Hays, Kans., which corresponds very closely to that of the region in which the 11-year-old wheat grew, varied from 12.8 to 26.5 inches. The season of 1932 was extremely humid, while the seasons of 1933 to 1936 were noted for extreme temperatures and low rainfall during the summer months. Periods of low temperature with much snow also occurred in the region during the 11 years. Since the wheat was apparently stored when thoroughly dry and of low moisture content, free from weevils, and relatively free from cracked grain, the fluctuations in atmospheric moisture and temperatures were never sufficient to cause the grain to go out of condition.

Milling and baking data were secured on the 11-year-old wheat through the courtesy of L. E. Leatherock, Chief Milling Chemist for the Kansas Milling Company, Wichita, Kans. The wheat had a test weight of 60.7 pounds per bushel, 11.0% moisture, and 11.33% protein, and milled out 71.6% total flour. The flour showed 0.496% ash,

10.00% protein, and 14.1% moisture, and was given a color score of 100 gray. The water absorption of the flour was 62.0%, the loaf volume 645 cc. The crumb color was graded as 100.5 gray white, with a texture of 99.0. Further notes indicate that the wheat milled satisfactorily considering its age, that it baked a good loaf of bread, and that the flour gave a dough with a long mixing time and excellent mixing tolerance. The milling and baking results compared favorably with those of the adapted varieties grown in the same region in 1938. —A. F. SWANSON, *Fort Hays Experiment Station*, *Hays*, *Kansas*.

AN APPARATUS DESIGNED TO FACILITATE PHOTOGRAPHY OF SMALL MACROSCOPIC OBJECTS

IN plant research as well as other fields, photography is an almost indispensable tool for picturing accurately to others phenomena observed. However, too often lack of proper equipment to give the "camera's eye" the necessary detail has resulted in failure to reproduce effectively the phenomena actually seen by the worker.

The apparatus shown in Fig. 1 was designed to give a uniform lighting of sufficient intensity to allow for a long exposure necessary for good detail in photographic reproductions. As can be seen in the photograph, this apparatus is essentially a box 30 by 36 inches and 20 inches high, mounted on rollers. On the top of the box is a ground-glass bottom tray with the same outside dimensions as the box and 3½ inches deep. This tray is water-proof and when objects such as root systems of plants are being photographed water is added to the tray. The roots flow out into a more normal position and have almost the same appearance that they would if they could be photographed in the soil. An example of this is shown in Fig. 2.

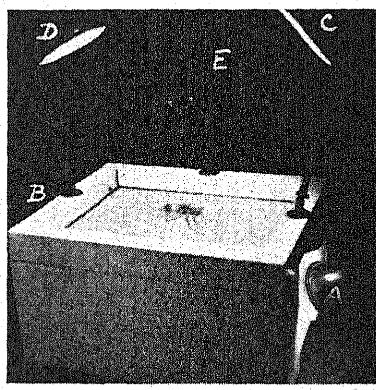

FIG. 1.—Photographic apparatus.

Lighting from below is supplied indirectly through the glass in the bottom of the tray thus eliminating minute shadows which have a tendency to cloud the detail. The light from photofloods (A) and (B) strikes the bottom of the box which has a highly polished surface and are reflected up through the glass bottom of the tray. Light from above is supplied by photofloods (C) and (D) which are mounted on double-jointed telescopic pipes which make adjustment to the desired height and angle easy.

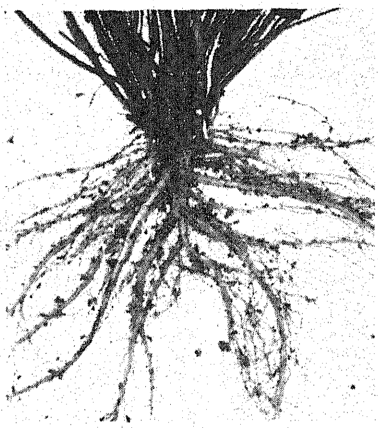

FIG. 2.—Nodulation produced by root nodule bacteria on red clover.

The camera (E), in this case an Eastman (Recomar 33), is mounted with an optipod on a double-jointed telescopic pipe similar to the upper photofloods. This gives the camera a rigid mount and allows for easy manipulation for the proper height and centering of the object being photographed. The camera should have a ground-glass focus which aids considerably in close-up photography.

This piece of equipment was constructed in our laboratory and has been used in photographing a wide variety of objects, including plant roots, stems, leaves and seeds, petri dishes showing colony growth of bacteria, copying graphs, and many other objects occupying an area ranging from 10 to 500 sq. in. and has given excellent results.

The approximate cost of construction, complete except for the camera, is about $20. Besides the saving in time and film, this equipment has more than paid for itself with photographs having greater detail and accuracy.—J. C. BURTON and L. W. ERDMAN, *The Nitragin Company, Inc., Milwaukee, Wis.*

BOOK REVIEWS

ELEMENTS OF PLANT PATHOLOGY

By Irving E. Melhus and George C. Kent. New York: The Macmillan Company. X+493 pages, illus. 1939. $4.

THIS is an excellent textbook for students who wish to complete their knowledge of plants. It will introduce to them the fact that plants do sicken, that they need medical assistance, that such assistance is available, and that it constitutes a branch of knowledge worthy of college attention.

The objects as set forth for the book are (1) to appreciate the influence of plant pathology on human affairs, (2) to acquire an understanding of health and disease in plants, (3) to understand the phenomena of parasitism, and (4) to acquire as much information as possible about the characteristics of diseases, their symptoms, cause, and control. A series of chapters deals with diseases classified according to cause including fungi, seed plants, nematodes, viruses, and nonparasitic agents. Reference to investigators is quite properly omitted in the interest of brevity and lucidity except where the name of the authority is of classical importance.

The authors have made a refreshing departure from the current practice of teaching plant pathology. They recognize that the subject is no longer just a study of organisms associated with sick plants. They have minimized the emphasis on mycology and have shifted it to parasitism. This, however, is chiefly a shift from taxonomy of the fungus to physiology. The fungus is still the major interest. Since the term, plant pathology, means a study of diseased plants, it is unfortunate that the authors did not complete the inevitable step and place the emphasis on the diseased plant itself, on its ability to withstand the disease, and on the factors that affect its ability to withstand disease. It seems that they might well have placed the emphasis where it is placed in animal pathology, on the organism that is diseased. In any case the text seems to warrant careful scrutiny by any teacher who needs a very readable, non-technical presentation of the present field of plant pathology. (J. G. H.)

GERMAN-ENGLISH SCIENCE DICTIONARY

By Louis de Vries. New York: McGraw-Hill Book Co., Inc. X+473 pages. 1939. $3.

THIS dictionary has been compiled for students in the agricultural, biological, and physical sciences. The author is Professor of Modern Languages at Iowa State College and had the collaboration of members of the Graduate Faculty in the preparation of this volume. Among these latter will be found several names familiar to agronomists, including J. M. Aikman in plant ecology, A. E. Brandt in statistics, R. E. Buchanan in bacteriology, R. M. Hixson in plant chemistry, E. W. Lindstrom in genetics, J. N. Martin in plant morphology and cytology, I. E. Melhus in plant pathology, F. B. Smith in agronomy, and others.

No attempt has been made to compile a complete list of names of all animals, plants, insects, or chemical compounds, but rather recourse has been had to the facility with which the German language lends itself to the compounding of words. In the 48,000 entries, therefore, stress has been placed on root stems from which the student can derive the meaning of almost any compound he would encounter. A list of abbreviations with both the German and English meanings is appended.

Well printed in a 5- by 7-inch size and with a flexible cover, the book makes an attractive and convenient volume for the student's desk. (J. D. L.)

GROWING PLANTS WITHOUT SOIL

By D. R. Matlin. New York: Chemical Pub. Co., Inc. VII+139 pages, illus. 1939. $2.

THIS is an enthusiastic (perhaps over-enthusiastic) discussion of the growing of plants in nutrient solutions. The over-enthusiasm of the author is shown by his statement that, "The greatest advantage of chemiculture lies in the direction of improving the quality of food products, of mineralizing the foods," etc. As an example of "mineralizing" foods, he states that "Dr. Charles Norther of Orlando, Florida, grew celery which upon chemical analysis showed twice the mineral content of the best grown elsewhere." The author seems to have overlooked the fact that the much publicized "mineralized" vegetables of Dr. Norther were grown in soil.

The first 46 pages of the book are devoted to a rambling but enthusiastic discussion of growing plants without soil highlighted by such startling statements as annual returns of $50,000 per tank-acre and the very low cost of the essential chemicals in 100-pound lots to show "why chemiculture is so inexpensive."

The remaining 91 pages are devoted to such unrelated subjects as making cuttings, hormones, budding, vitamins, list of state flowers, addresses of all agricultural experiment stations, and other miscellaneous material. (C. B. S.)

HANDBOOK OF CHEMISTRY

Compiled and edited by N. A. Lange, assisted by G. M. Forker and R. S. Burington, Sandusky, Ohio: Handbook Publishers, Inc. Ed. 3. XVIII+1850 pages. Fabricoid. 1939. $6.

THERE are several points which make this volume superior to all other works of its kind. The clearness of presentation as well as of the printing are beyond criticism in spite of the enormous quantity of information contained in the HANDBOOK. There is an increase of about 50 pages in the text and a small increase in the index.

The summarizing treatment of various groups of materials, as for instance the tables giving the melting point of various organic compounds, is of much help to the worker looking for general information on any subject. The quantity and variety of information included in

the volume make it not only useful but almost a necessary help to all dealing with the sciences. (Z.I.K.)

AGRONOMIC AFFAIRS

PROFESSOR SHAW, PROFESSOR MUSBACH, AND PROFESSOR HUTTON

SOIL science in general and the American Society of Agronomy and the Soil Science Society of America in particular lost three of its outstanding personalities during the past few weeks in the deaths of Professor Charles F. Shaw of the University of California, Professor F. L. Musbach of the University of Wisconsin, and Professor J. G. Hutton of South Dakota State College.

Professor Shaw died on September 12, following a brief illness. He had long been an active member of the American Society of Agronomy and also participated actively in the Soil Science Society of America, the International Society of Soil Science, and many other organizations.

Professor Musbach was killed in an automobile accident on September 14. He had been active in the American Society of Agronomy since the second year of its organization and at the time of his death was in charge of the soil investigations on the branch experiment stations of the University of Wisconsin.

Professor Hutton died at Brookings, South Dakota, on September 23. He had been continuously in the position of Associate Agronomist and later Professor of Soils in South Dakota State College, and in charge of soil research at the South Dakota Agricultural Experiment Station, since 1911. Just recently he published South Dakota Experiment Station Bulletin No. 325 entitled, "Thirty Years of Soil Fertility Investigations in South Dakota".

THE TRANSACTIONS OF THE THIRD COMMISSION

THE TRANSACTIONS of the meeting of the Third Commission of the International Society of Soil Science made its appearance just preceding the meeting of the Commission at New Brunswick, N. J., the latter part of August. The volume makes 185 pages and is paper covered.

Dedicated to Doctor J. G. Lipman, the volume opens with a tribute to Doctor Lipman by Doctor D. J. Hissink. There follows then the twenty-five papers presented before the Commission under the three general headings of "Legumes and Legume Bacteria," "Microbiology of Soil Organic Matter", and "Azotobacter and Its Significance in Soil Processes". A list of the papers on soil microbiology presented before the Third International Congress for Microbiology in New York City early in September is appended.

THE 1940 TOBACCO FERTILIZATION RECOMMENDATIONS

RECOMMENDATIONS for the fertilization of flue-cured, sun-cured, and shipping tobacco to be grown on average soils in Virginia, North and South Carolina, Georgia, and Florida in 1940 have been prepared by the joint Tobacco Research Committee of which Professor C. B. Williams of the North Carolina State College of Agriculture at Raleigh is chairman. The report is in mimeographed form and may be obtained upon request to Professor Williams.

ABSTRACTS OF LITERATURE PERTAINING TO BIOCLIMATOLOGY AND BIOMETEOROLOGY

ANNOUNCEMENT has been made by BIOLOGICAL ABSTRACTS of a more complete abstracting service and segregation of the current research literature in bioclimatology and biometeorology. A section entitled "Bioclimatology-Biometeorology" will soon appear within the section on "Ecology" in BIOLOGICAL ABSTRACTS, with Robert G. Stone of the Blue Hill Observatory, Harvard University, as editor.

ERRATUM

IN the article entitled "Heat Resistance in Oat Varieties" by Franklin A. Coffman, pages 811–817 in the September number of this JOURNAL, the word "inhibitional" in line 7, paragraph 2, under "Discussion" on page 816, should read "imbibitional".

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THE OXIDATION-REDUCTION POTENTIAL OF ALKALINE CALCAREOUS SOILS IN RELATION TO PUDDLING AND ORGANIC MATTER DECOMPOSITION[1]

T. F. BUEHRER, W. P. MARTIN, AND R. Q. PARKS[2]

ALTHOUGH the study of redox potentials of soils has in recent years received attention at the hands of numerous investigators (1, 3, 8, 15, 18, 21, 23),[3] such studies have been confined almost entirely to soils of humid regions and to the behavior of soils under water-logged conditions. By way of contrast, the alkaline calcareous soils of the desert present certain characteristics which offer opportunity for application of the redox potential method. They contain an exceedingly active microflora and the decomposition of organic matter proceeds at a very rapid rate, as has been shown by Oberholzer (14). Because of their low organic matter content, such soils easily pass into the puddled state when cultivated under irrigation, as found by McGeorge (11). Under such circumstances anaerobic conditions have been shown to exist by Breazeale and McGeorge (4) with attendant loss of nitrogen by denitrification and serious inhibition of plant growth. These authors showed further that the incorporation of organic matter in a puddled soil will not of itself correct the puddled condition and that the toxic substances formed in the anaerobic decomposition are at times so stable that they are not readily oxidized to non-toxic forms when the soil is allowed to dry out and become thoroughly aerated.

It seemed of interest, therefore, to apply this method to some typical desert soils in their normal and puddled states, and in the presence and absence of actively decomposing organic matter. The present paper presents the results of certain phases of this investigation. For purposes of comparison a similar study was conducted on a typical soil from a humid region.

[1]Contribution from the Department of Agricultural Chemistry and Soils, Arizona Agricultural Experiment Station, Tucson, Ariz. Published with approval of the Director. Also presented before the Western Society of Soil Science, Stanford University, Palo Alto, Calif., June 26–28, 1939. Received for publication August 15, 1939.

[2]Physical Chemist, Assistant Soil Microbiologist, and Graduate Assistant, respectively.

[3]Figures in parenthesis refer to "Literature Cited", p. 914.

METHOD OF EH MEASUREMENT

The technic of measurement employed was substantially that of Brown (5), with certain modifications to make the method applicable to the soils being studied. The electrode system consisted of a bright platinum wire *welded to the copper wire* leading to the potentiometer, and a calomel cell made up with saturated potassium chloride and connected with the soil suspension by way of an agar bridge. The potentials were measured with a Leeds and Northrup potentiometer. The authors desire to emphasize at this point the difficulties which may be encountered when the conventional mercury contact between the platinum electrode and the potentiometer wire is employed. Very erratic potentials were obtained under these conditions which were attributed to a poisoning effect of the mercury. The results of a few typical experiments in this connection are shown in Fig. 1. It will be seen that concordant potential values could not be secured with any group of three electrodes unless the mercury contact was eliminated (Fig. 1, D). After rather exhaustive tests with 18 electrodes, prepared in the above manner, it was found that as many as 12 electrodes in one soil suspension agreed to within 2 millivolts, and when distributed into as many as six duplicate samples of a given soil, they agreed to within 3 or 4 mv. The potentials were usually constant and in substantial agreement within 15 minutes after insertion of the electrodes.

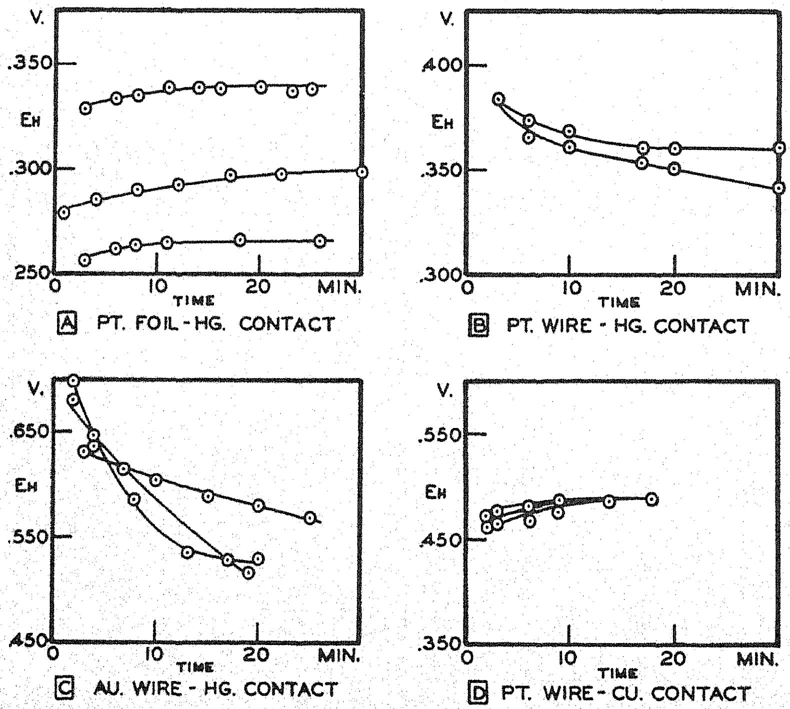

FIG. 1.—Reproducibility of metal electrodes for Eh measurement.

Another factor of importance is the time of standing before the measurement is made. Investigators have found it difficult to obtain reproducible results in soil suspensions because the potentials tended to drift over wide limits. Peech and Batjer (16) and Bradfield and co-workers (3) avoid this drift by suspending the soil in 0.1 N sulfuric acid solution which they claim serves to poise the system more effectively. In alkaline calcareous soils such treatment is not desirable, since the acid brings substances into solution which affect the potential. Volk (20) found an average difference of over 200 mv. between the potentials of soil: water suspensions and the same soils suspended in sulfuric acid.

Other workers have recommended allowing the suspensions to stand for varying lengths of time before making the Eh measurements. Darnell and Eisenmenger (7) recommended shaking the sample for 2½ to 3 days, while Peech and Batjer (16) allowed their syspension to stand for 24 hours. Brown (5) suggests centrifuging the suspensions with the platinum electrodes in place. Experiments in the present investigation showed that the latter procedure slowed up the attainment of equilibrium unless the electrodes were placed in the soil paste at the bottom of the tube.

It is also evident that when organic matter is added to a soil, the reducing conditions thus imposed will cause the Eh value to decrease, and it becomes important to know the time interval within which the value remains constant. An experiment was therefore carried out with 1:5 water suspensions of an arid and a humid soil, both with and without organic matter (alfalfa), in which the potentials were observed over an extended period of time (24 hours).

The curves so obtained, which are typical of numerous experiments of this kind, are shown in Fig. 2. It is found that where organic matter had not been added, the potential remained constant throughout the period of measurement. When alfalfa was added to the samples, however, the potential remained constant

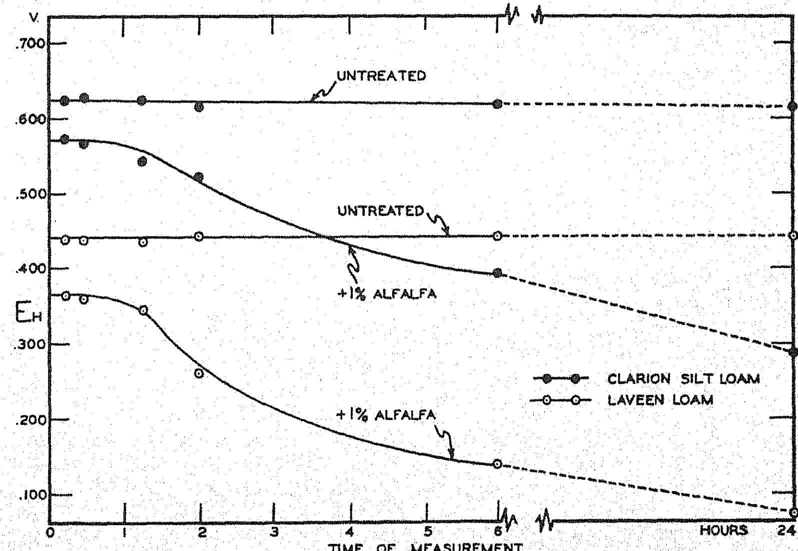

FIG. 2.—Change in Eh of Clarion silt loam and Laveen loam during period of measurement, both in presence and absence of alfalfa.

for only 20 to 30 minutes, thereafter decreasing sharply with the time. In all subsequent studies the readings were therefore taken within 30 minutes after preparation of the suspensions. Some investigators (5, 20) have considered it necessary to remove oxygen from the soil suspensions before making the Eh measurements because, as shown in a subsequent section, depletion of the oxygen by an active soil microflora when in contact with the medium for long periods of time leads to a drop in the potential. Inasmuch as equilibrium was reached in our experiments before an appreciable change in redox potential occurred, even in the presence of fresh alfalfa, removal of the oxygen present with nitrogen was unnecessary.

It might be mentioned at this point that the authors were unable to secure reproducible results on soils at field moisture contents by the procedure of Burrows and Cordon (6). This difficulty may have been due to imperfect contact of the electrodes with the sample; it was eliminated by the use of water suspensions of the soils after they had been incubated at an optimum moisture content.

PROCEDURE FINALLY ADOPTED

Suspensions of the soil in a ratio of 1 part of soil to 5 of water were allowed to come to a constant temperature of 30° C in the water bath. Before the electrodes were placed in the suspension, they were rinsed with water, heated to redness in a Bunsen flame, rinsed again, and inserted in the suspension bottle. The samples were shaken and the potentials measured at 5-minute intervals over a period of 20 to 30 minutes. The observed values were calculated to the normal hydrogen electrode taken as zero and to a constant reference pH value of 7.0.

Eh-pH RELATIONSHIPS IN SOILS

Since the redox potential is a function of the pH value of the soil, it is necessary to convert observed Eh values to the same pH value in order to make the data comparable for different soils. Before such a conversion can be made, it is obviously necessary to find the proportionality factor between these two quantities. Willis (22), Heintze (8), Bradfield and associates (3), and others have shown for a wide variety of soils that when Eh values are plotted against pH values, a straight line of negative slope is obtained. This result is consistent with the thermodynamic equation for the redox potential of known organic systems as derived by Hewitt (9) and Michaelis (13).

In studying the Eh:pH relationship, it has, as previously mentioned, been customary for investigators (3, 16, 19), to change the pH of the soil by adding different amounts of acid and base before measuring the redox potentials. It has been assumed that these additions do not change the true Eh of the system. However, the acid may bring iron and other inorganic oxidizing agents into solution and seriously affect the potential. Since the organic (humus) constituents of the soil are slightly soluble in acids and therefore also extensively soluble in alkalies, such treatment may change the ratio of oxidant to reductant present in solution. Since the arid soils which constitute the basis of the present study were nearly all calcareous and high in iron, the method of acid-base addition was found to be unsatisfactory.

The results of such studies made by various investigators are shown in Table 1 and Fig. 3. In some instances the curves deviate strongly

TABLE 1.—*Comparison of Eh : pH ratios for different soils as found by different investigators.**

Designation of curve in Fig. 3	Soil	dEh/dpH	Investigators
	Acid-Base Addition Method		
A	Clarion silt loam	−0.076	Buehrer, Martin, and Parks
B	Sassafras silt loam	−0.066	Buehrer, Martin, and Parks
C	Palos Verdes gravelly sandy loam	−0.076	Buehrer, Martin, and Parks
D	Pima loam	−0.083	Buehrer, Martin, and Parks
E	Average of 5 Palestine soils	−0.053	Puri and Sarap (17)
F	North Carolina peat	−0.067	Willis (22)
G	Well oxidized New York soil	−0.100	Bradfield, Batjer and Oskamp (3)
H	Reduced soil, high in organic matter	−0.093	Bradfield, Batjer and Oskamp (3)
QH	Equi-molal mixture of quinone and hydroquinone	−0.059	Michaelis (13)
	Sandy soils from Massachusetts	−0.054	Darnell and Eisenmenger (7)
	Colloid from Ohio soils	−0.059	Kohnke (10)
	Well-oxidized silt loam subsoil from New York	−0.066	Peech and Batjer (16)
	Slightly reduced silt loam subsoil from New York	−0.063	Peech and Batjer (16)
	Average of several English soils	−0.060	Heintze (8)
	Amity clay loam from Oregon	−0.080	Stephenson, Schuster and Spulnik (18)
	Average of 132 Alabama soils	−0.067	Volk (20)
	Dilution Method		
	Tucson loam	−0.068	Buehrer, Martin, and Parks
	Mohave clay loam	−0.068	Buehrer, Martin, and Parks
	Pima loam	−0.069	Buehrer, Martin, and Parks
	Pima silty clay loam	−0.066	Buehrer, Martin, and Parks

*In Table 1 and Fig. 3 the data recorded for other investigators have been taken from published papers and are subject to the errors inherent in the process of obtaining slopes from the small published graphs.

from linearity; nor are the slopes of the lines equal. Their average value is found to be about −0.075, which is considerably greater than the theoretical value, −0.060. This difficulty was obviated by taking advantage of the fact, pointed out by Baver (2) and by McGeorge (12), that when an alkaline soil is continuously diluted, the pH value increases, attaining a limiting value at a soil:water ratio of 1:10 and thereafter remaining constant. At dilutions ranging from 1:½ to 1:25, the pH values of such soils may increase by as much as 1.5 units. This phenomenon makes it possible to secure a pH change in the soil

by simple, spontaneous hydrolysis without disturbing the Eh value of the soil, except insofar as it may be influenced by the pH change itself.

The results so obtained are shown in Fig. 3 in which the soil:water ratios were varied from 1:1 to 1:25. The curves, almost without exception, are strictly linear, and the slope is found to have an average value of –0.068. This value approaches close to the theoretical –0.060 slope for some of the common organic oxidation-reduction systems such as the quinone-hydroquinone (13), succinate-fumarate (9), and lactate-pyruvate (9) systems, the latter two being common in carbohydrate decomposition.

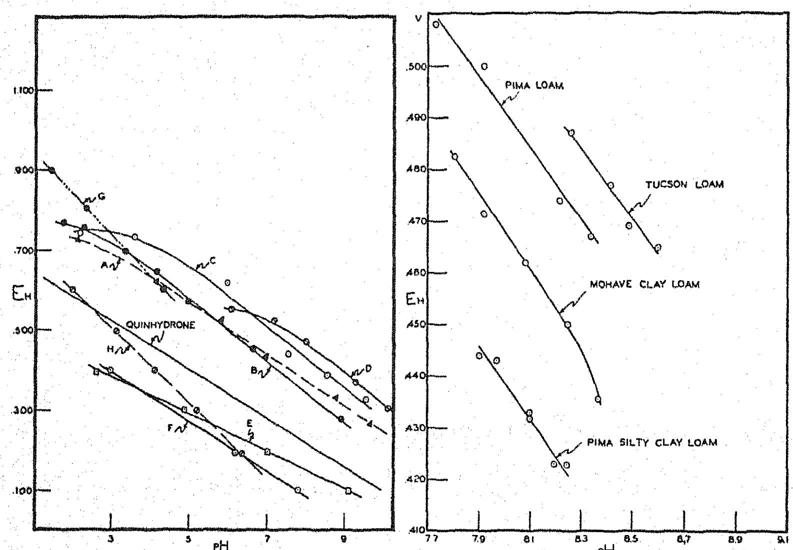

FIG. 3.—*Left*, variation of Eh with pH by acid-base addition; *right*, variation of Eh with pH by dilution method.

A comparison of the slope values obtained by the two methods is shown in Table 1. It will be seen that those in which the slope was determined by the acid-base addition method were principally humid soils, about half of which gave values averaging close to the theoretical value. The remainder, which included two desert soils, namely, Pima loam and Palos Verdes sandy loam, gave slopes considerably greater, i.e., of the order of –0.080. The group of four desert soils studied by the dilution method gave closely concordant values averaging –0.068. The latter value was accordingly employed in calculating the Eh values to the chosen reference pH value of 7.0.

INCUBATION STUDIES

For the incubation studies two soils were used: Mohave clay loam, a typical arid soil, and Clarion silt loam, a humid soil from Iowa. Part of the samples were treated with alfalfa; part left untreated. Part of the samples were kept continuously in the puddled condition

throughout the period of incubation; others were left unpuddled. All combinations and permutations were tried, and the experiment was carried out in duplicate.

The samples were placed in large petri dishes, 7½ inches in diameter and ¾ inch deep, maintained at the optimum field moisture content, and incubated at 30° C. They were puddled and repuddled daily by working with a spatula. Vertical sections of the soil were taken periodically with a large cork borer and diluted 1:5 for the redox potential measurements. The pH determinations were made on a separate portion of each suspension with the Beckman pH meter.

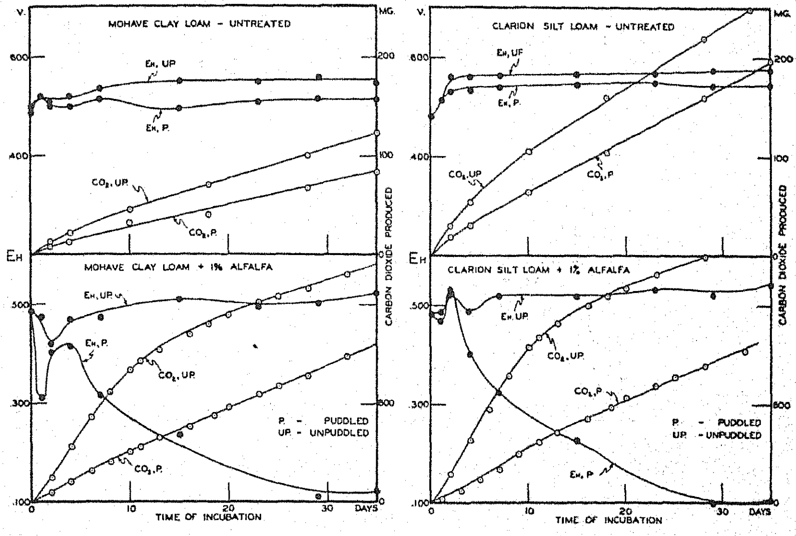

FIG. 4.—*Left*, variation of Eh of Mohave clay loam with time of incubation; *right*, variation of Eh of Clarion silt loam with time of incubation.

By way of correlation with the Eh data, the rate of decomposition of the alfalfa was observed by measuring the carbon dioxide evolved. Sixteen samples similar to those above were prepared in 500-cc Erlenmeyer flasks. They were kept moist and a portion of them puddled daily, but the flasks were stoppered during the incubations. Daily carbon dioxide determinations were made by absorption in barium hydroxide according to the customary procedure.

The results are shown in Fig. 4 for Mohave clay loam and Clarion silt loam. The curves in these two figures are strikingly similar. The carbon dioxide evolution curves show that puddling of the soils decreased the rate at which alfalfa underwent decomposition to the end products of carbon dioxide and water. Even in the untreated samples, which contained less than 1% of organic matter, puddling decreased the rate.

Reflecting the differences in decomposition rate as indicated by carbon dioxide evolution, puddling also has a marked influence upon

the Eh value of the soil. In the untreated samples after 10 days' incubation, puddling resulted in an Eh value some 40 to 50 mv. lower than for the same soils under normal conditions. When alfalfa was present puddling caused an extremely large drop in potential, amounting in 30 days to approximately 400 mv.

A striking feature of these curves is the marked initial drop in potential in all cases where alfalfa was present, whether the samples were puddled or unpuddled. This drop was followed by a sharp increase which tapered off to a limiting value. In the case of the puddled soils, there was a similar sharp increase following the initial drop, but instead of attaining a constant limiting value, the Eh again *decreased* to a final limiting value. Comparing this behavior with that of the carbon dioxide evolution curves, we note the complete absence of such a lag phase during the initial stages of the decomposition process. This phenomenon cannot be attributed to changes in microbial activity in the samples. Another possible explanation suggests itself, however. It has been observed that when an inert electrode is immersed in a sugar solution, such as sucrose or glucose, the electrode potential falls. This effect is thought by Hewitt (9) to be due to some unknown oxidation-reduction system present in the sugar solution. Perhaps a negative potential is assumed by the soil while the water-soluble carbohydrates are still present in appreciable amounts, but since they are promptly utilized by the micro-organisms, the potential may rise and assume a value characteristic of the less soluble but readily available fractions, such as the hemicelluloses and celluloses.

A similar effect was observed in another experiment illustrated in Fig. 5 in which the samples were incubated under normal, that is, unpuddled, conditions. Here again a marked drop in the potential was observed, the difference in the minimal Eh values between the untreated soil and the same soil treated with 1% alfalfa was as high as 150 mv. This phenomenon has also been observed by Darnell and Eisenmenger (7) who attributed the difference to oxygen depletion. In the present case the writers do not believe the effect to be due to the oxygen potential but rather to peculiar characteristics of the metabolic products of alfalfa, since both the treated and untreated samples had been suspended in distilled water from the same source and the potential determined before any appreciable change in the partial pressure of oxygen could have taken place.

OXYGEN POTENTIAL

It was considered of interest at this point to determine whether or not the assumption of an oxygen potential as entering into the measurement of the redox potential of a soil was justifiable. Untreated samples of Pima loam were suspended in water and redox potential measurements made at periodic intervals. The dissolved oxygen present was removed from the suspensions by aspirating with nitrogen. The results are shown in Fig. 6A. It should be emphasized that no organic matter had been added to this sample.

It appears that the oxygen potential must enter in some way into the redox potential, since the value of the latter in a nitrogen atmosphere dropped about 300 mv. in less than 10 hours' time. No change

in potential occurred in the suspension through which no gas was passed indicating that bacterial action was probably so slow that the

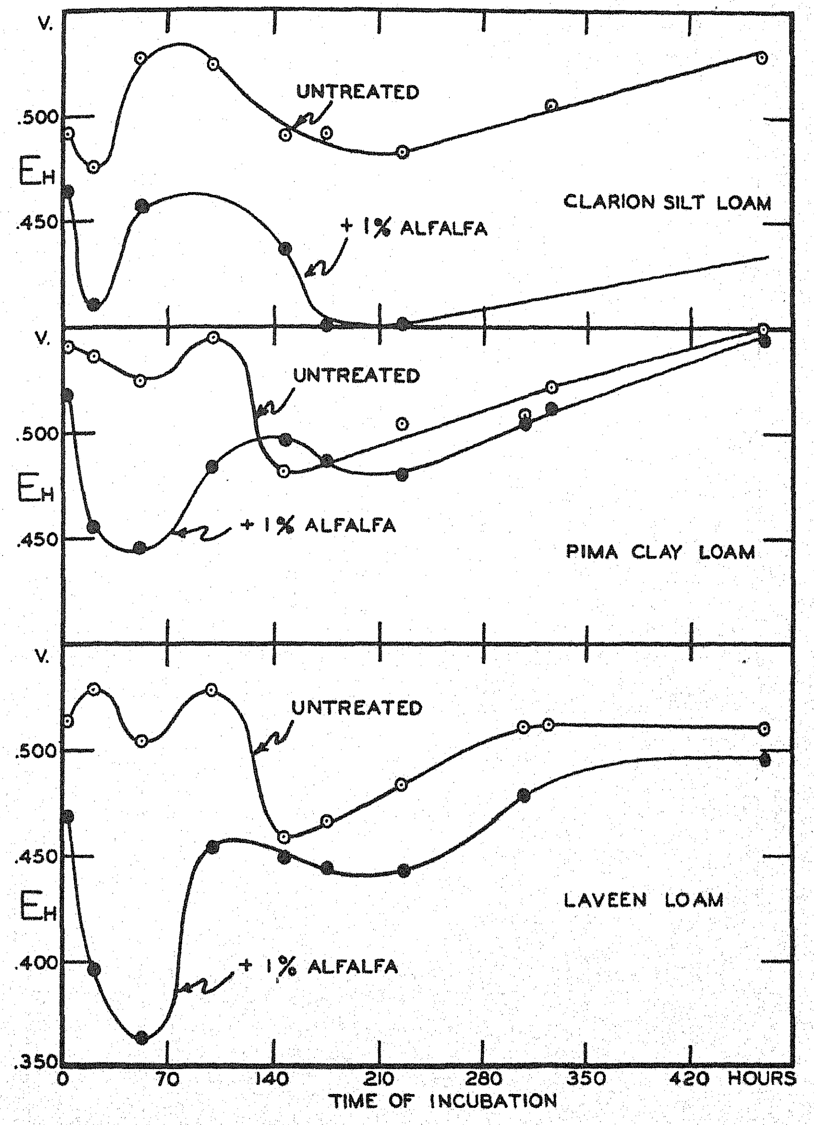

FIG. 5.—Change in Eh of normal (unpuddled) soils, with time of incubation, both in presence and absence of alfalfa.

bacteria were incapable of utilizing the oxygen faster than it could diffuse in from the atmosphere, or of accumulating sufficient reduced products under the water-logged conditions to lower the potential.

On the other hand, when oxygen was passed through the suspension, a marked rise in the potential resulted.

An experiment similar to the preceding was carried out, but in this case alfalfa had recently been incorporated with the soil and

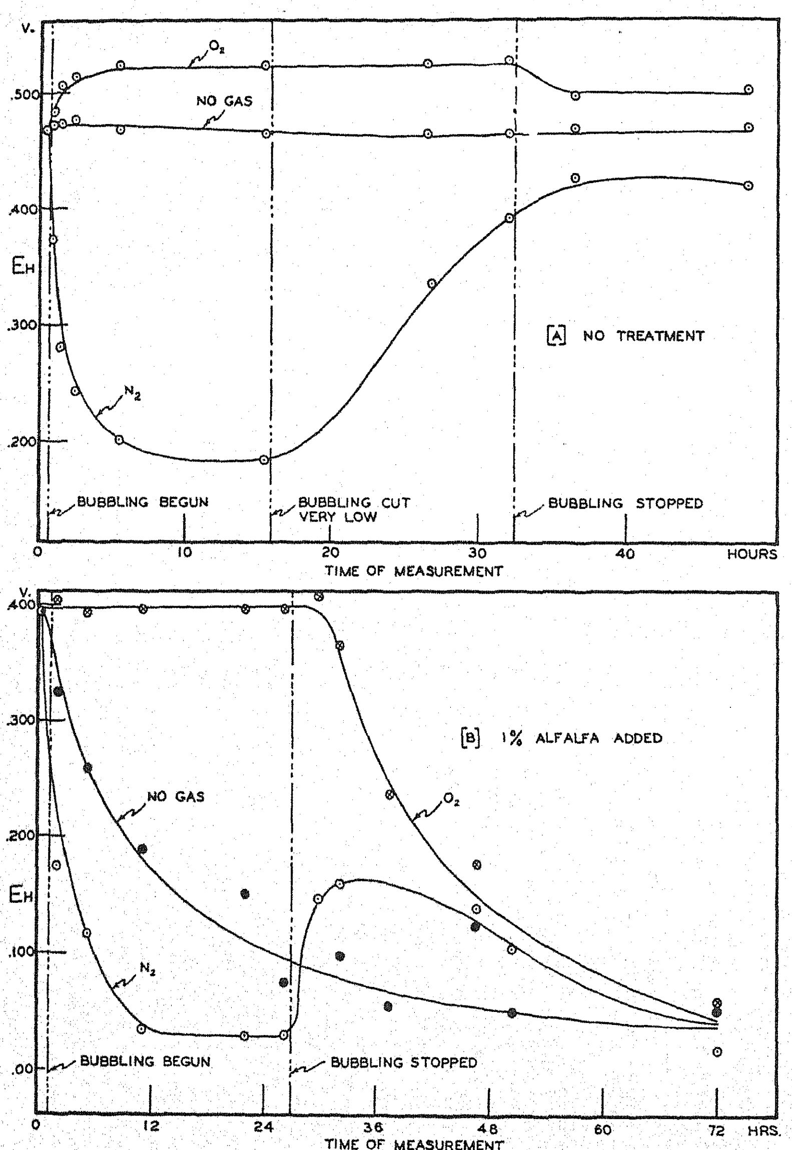

FIG. 6.—Variation of Eh of Pima loam, with time of measurement, in an atmosphere of air, nitrogen, and oxygen, respectively. A, no treatment; B, 1% alfalfa added.

allowed to decompose partially before preparation of the water suspensions. The results are plotted in Fig. 6B. It will be observed that an immediate sharp drop in potential occurred in both the sample through which no gas was passed and the one treated with nitrogen. In the case where oxygen was bubbled through, the potential remained constant until the bubbling was stopped, and thereafter it dropped sharply. It will also be noted that the Eh value of all three samples eventually became substantially constant and equal to approximately 50 mv.

This behavior may be accounted for in two ways, *viz.*, (1) the drop in potential may be due to a depletion of oxygen from the medium, either as a hydrogen acceptor in the decomposition process or by having been swept out of the suspension by the carbon dioxide produced in the decomposition; or (2) it may be due to the accumulation of reduced compounds from either reversible or irreversible oxidation-reduction systems. In this case the oxygen passing through the suspension prevents a drop in the potential by maintaining aerobic conditions.

That the latter explanation holds in part for puddled soils which are anaerobic in their environment is indicated by the fact that wide differences in potential existed between these soils and those in the unpuddled state, even though both were suspended in distilled water with identical amounts of oxygen present and measured before any appreciable change could occur. Since an identical amount of oxygen was present in each case, the differences must be attributed to some cause other than oxygen depletion.

SUMMARY

1. A study has been made of the redox potentials of arid alkaline soils with respect to organic matter decomposition, puddling, and Eh-pH relationships.

2. It was found that the Eh-pH relationship in such soils could be more satisfactorily studied by making use of the pH change due to simple dilution with water than by adding acid or alkaline solutions. The slope of the line for such soils is found to be −0.068, which approximates closely to the theoretical value for the organic systems commonly present during carbohydrate decomposition.

3. Puddling causes a marked decrease in the redox potential, particularly when the soil has been treated with alfalfa. It is believed that factors other than oxygen depletion are responsible for this decrease.

4. A sharp initial drop in the potential occurs in both puddled and unpuddled soils that have been treated with alfalfa. This effect may be attributed principally to the nature of the reduced compounds formed during the decomposition.

5. Measurements of redox potential made in an atmosphere of nitrogen and oxygen, respectively, give evidence of the existence of an oxygen potential, inasmuch as the redox potential drops sharply when nitrogen is bubbled through and increases in the presence of oxygen.

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THE RELATION BETWEEN SOIL REACTION, EROSION, AND AGGREGATION OF SILT AND CLAY IN CLARKSVILLE LOAM[1]

H. T. ROGERS[2]

WHILE studying the effect of soil reaction on the growth and composition of annual flowers, Shear (16)[3] observed that the more acid plats of Clarksville loam were undergoing severe erosion. Fig. 1 shows the eroded condition of one of the most acid plats.

The role of calcium in the formation of water-stable aggregates in the soil is controversial. Bradfield (4, 5) found that the coagulating value of a colloidal clay varied widely with slight changes in H-ion concentration. Reporting on the relation of exchangeable cations to the physical properties of soils, Baver (1) concluded that H-saturated soils were always less flocculated than the original untreated soil and that hydrogen flocculated the coarser particles but had a peptizing effect on the colloidal material.

More recently these investigators have pointed out some of the limitations of calcium in producing a desirable soil structure. Baver (2) stated that factors other than Ca-ion saturation are dominant in causing stable aggregation and Bradfield (6) pointed out that the formation of water-stable aggregates is much more than flocculation of colloids.

Greenhouse and laboratory investigations by Peele (12, 13), Lutz (9), and Browning (7) show that calcium in itself plays a minor role in improving the structure of heavy-textured soils. Metzger and Hide (10) found that liming improved the aggregation of a silt loam soil which had an original pH of 5.7 when followed by a growth of sweet clover or red clover but had no beneficial effect on the aggregation of unleached fallow soil in the greenhouse. It is generally conceded that an interaction of factors may be responsible for the flocculation, granulation, and aggregation of soil colloids.

DESCRIPTION OF AREA AND PLAT TREATMENTS

The five 1/40-acre plats of Clarksville loam used in this study were remarkably uniform in texture and had an original pH of 5.3. The 5 to 7 inches of yellowish-gray loam surface soil were underlain by a brownish-yellow, friable clay loam. Elevation readings showed the micro-relief of the area to be very uniform with 8.7% slope to the southeast. The treatments of the plats selected and the resulting pH, along with the textural composition of the surface soil are shown in Table 1.

Ground limestone and $Al_2(SO_4)_3$ were applied at the indicated rates to the surface of these plats. They were plowed several times during the summer of 1933 and subjected to clean cultivation of annual flowers for the next three years. Small grain cover crops were seeded in the fall of 1933 and again in 1935. A rye

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[3]Figures in parenthesis refer to "Literature Cited", p. 922.

cover crop which was grown during the winter of 1935-36 was cut and raked off the following spring. During 1937 and 1938 the plats were left to volunteer weeds and grasses.

As can be seen in Fig. 1 the more acid plats supported a poorer growth of vegetation. Seven of the 13 varieties of flowers grown obtained their average maximum growth at a soil reaction between pH 7.0 and 7.5, according to Shear (16). The other six varieties made their best growth at a pH between 5.5 and 7.0.

TABLE 1.—*Treatment, texture of soil, resulting pH, and extent of erosion of plats.*

Plat No.	Treatment (1933), lbs. per acre	Texture of soil, %			pH (1938)	Degree of erosion
		Sand	Silt	Clay		
1	6,120 lbs. $Al_2(SO_4)_3$	38.6	41.9	19.3	4.46	Severe sheet erosion and incipient gullying
2	1,933 lbs. $Al_2(SO_4)_3$	40.6	39.2	20.2	4.78	Moderate sheet erosion with rills evident after intense rains
3	None	36.4	45.1	18.5	5.32	Slight sheet erosion
4	11,680 lbs. ground limestone	34.1	46.6	19.3	7.26	Very little sheet erosion and plot well stabilized for cultivated land of this slope
5	1,933 lbs. $Al_2(SO_4)_3$ and 40,000 lbs. ground limestone	40.2	42.5	17.3	7.41	Not appreciably different from plat No. 4

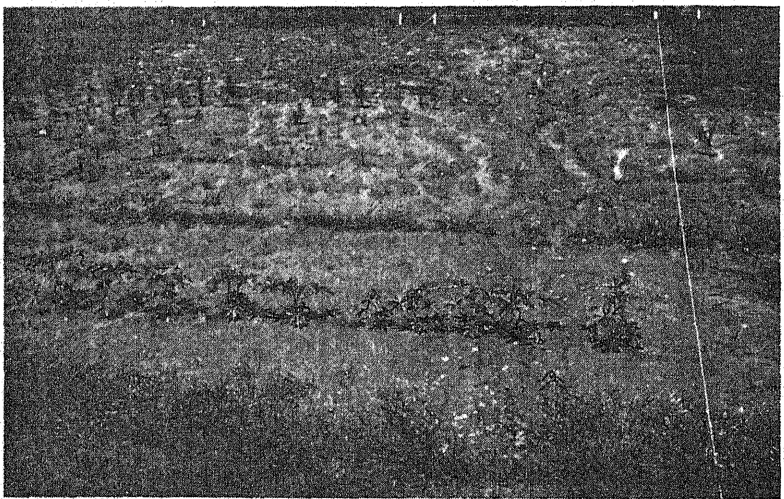

FIG. 1.—Severe erosion on acid plats of Clarksville loam, Blacksburg, Virginia.

PROPERTIES OF SOIL INVESTIGATED AND METHODS EMPLOYED

In order to determine whether the relationship observed in the field between soil reaction and extent of erosion could be attributed, in part at least, to certain physical properties of the soil which have been recognized as factors influencing erodibility, the state of aggregation of the surface soil on the different plats was investigated by a combination of wet-sieving and hydrometer methods of analysis. Thirty-five soil samples were taken during the period of June, August, and November, 1938, with a 3-inch core sampler (Fig. 2) and air dried for aggregate analysis studies. A modification of the wet screening method developed by Yoder (18) was employed to determine the distribution of coarse aggregates> 0.1 mm in size. The factor "degree of aggregation" was calculated from hydrometer analyses of the silt and clay content of completely dispersed and undisturbed soil samples. A procedure was used for the hydrometer aggregate analysis in which a 50-gram sample of soil was permitted to slake through a 5-mm sieve in a shallow pan of water before transferring to the hydrometer jar. Except for this technic the procedure varied only in some of its details from the method suggested by Bouyoucos (3) and gave close checks on duplicate samples. A glass electrode pH meter was used to determine the H-ion concentration of these samples. Organic matter was calculated from total carbon determinations which were made with a Fleming combustion furnace using ascarite absorbent. "Soluble" aluminum values were taken from a curve (Fig. 4) based on data presented by Shear (16). He secured the data from surface soil samples of this experimental area, using Morgan's (11) sodium acetate extracting solution.

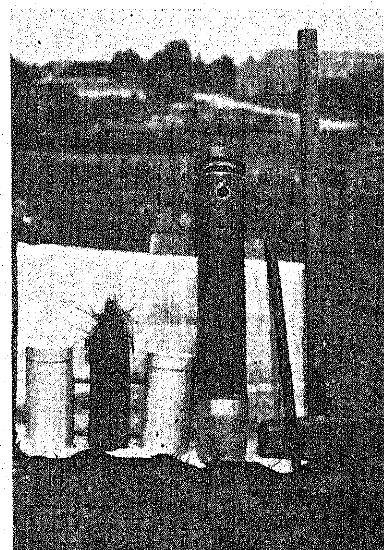

FIG. 2.—Soil sampling apparatus for aggregation studies.

DISCUSSION OF RESULTS

DEGREE OF AGGREGATION AND H-ION CONCENTRATION

Field observations of the behavior of these plats showed increasing sheet erosion as the acidity increased, irrespective of $Al_2(SO_4)_3$ or other treatment (Table 1). These ratings as to extent of erosion which had occurred were made at the end of the five-year period. It was apparent after the first year that some of the plats were undergoing severe sheet erosion which continued at an accelerated rate as the experiment progressed. The amount of plant growth on the different plats naturally affected their susceptibility to erosion. The influence of this factor on either extent of erosion or soil aggregation was lessened by the plats being in rows of clean-cultivated annual

flowers rather than a close-growing crop during the season when most of the erosion occurred. Removal of the 1935–36 cover crop reduced any effect of this crop on the organic matter content of the various

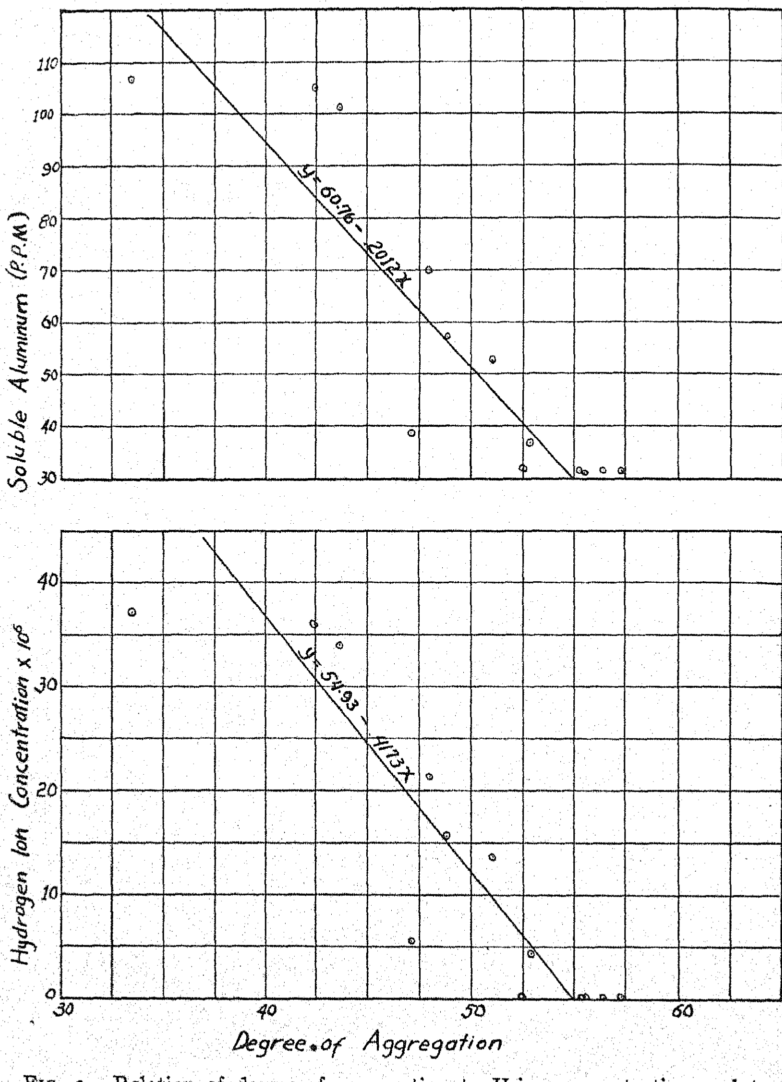

FIG. 3.—Relation of degree of aggregation to H-ion concentration and to soluble aluminum.

plats. The factor, degree of aggregation, which was used by Lutz (8) should be a good indication of the state of dispersion of the silt and clay particles in a soil. Degree of aggregation shows that fraction of

the total silt and clay in the soil when dispersed which is combined into units greater than silt size when the soil has its natural structure.

A highly significant negative correlation was found between aggregation and H-ion concentration as shown by the data in Tables 2, 3, and 4. While the percentage hydrogen saturation of the cation exchange capacity would be a good basis for studying the effect of hydrogen on the aggregation of a soil, a good correlation would be expected between percentage hydrogen saturation and H-ion concentration (15). It follows that about the same relationship would exist between percentage hydrogen saturation and degree of aggregation as was found between H-ion concentration (as measured by pH) and aggregation. Both degree of aggregation and percentage aggregates >0.1 mm in size were closely related to soil reaction. A correlation coefficient of $-.895 \pm .0576$ was found between degree of aggregation and H-ion concentration. The dispersion of the data from the regression line is illustrated in Fig. 3 where the average values for each sampling date are plotted. Distribution of the coarser aggregates, as determined by screening under water, is shown in Table 2.

TABLE 2.—*Distribution of aggregates in Clarksville loam at various acidity levels.*

Size of particle, mm	pH				
	4.46	4.78	5.32	7.26	7.41
Coarse Units (Wet Sieving), %					
2.0–5.0	3.9	4.7	6.0	3.9	6.0
1.0–2.0	3.9	4.4	5.9	4.7	6.0
0.5–1.0	5.6	5.8	6.5	6.4	6.6
0.25–0.5	7.9	9.0	10.1	10.8	12.0
0.1–0.25	15.8	16.6	16.3	18.6	19.5
Total >0.1	37.1	40.6	44.3	44.4	50.0
Small Units (Aggregate Hydrometer), %					
Total <0.05	36.3	30.1	31.2	28.9	26.9
Total <0.01	4.9	7.8	8.5	7.2	7.5
Total <0.005	1.5	3.0	4.3	3.4	3.6

TABLE 3.—*Degree of aggregation compared with H-ion concentration, soluble aluminum, and organic matter.**

Plat No.	Degree of aggregation, %†	Soil reaction		Soluble aluminum, p.p.m.	Organic matter, %
		H-ion concentration x 10^6	pH		
1	40.8	35.200	4.46	103.6	1.49
2	49.2	16.670	4.78	59.6	1.29
3	50.9	4.800	5.32	37.2	1.88
4	56.1	0.055	7.26	31.3	1.64
5	55.1	0.039	7.41	31.5	1.76

*These data are weighted averages of analyses of samples taken in June, August, and November, 1938.

†Percentage of the total silt and clay in aggregates >0.05 mm.

TABLE 4.—*The degree of association between aggregation of particles and certain related properties of Clarksville loam.*

Factors correlated	Correlation coefficient (r)	Number of cases
Degree of aggregation and H-ion concentration	$-0.895^* \pm 0.0576$†	13‡
Degree of aggregation and soluble aluminum	-0.887 ± 0.0638	13‡
Degree of aggregation and percentage organic matter	0.360 ± 0.1492	35
Percentage aggregates >0.1 mm and H-ion concentration	-0.853 ± 0.0786	13‡

*Corrected for small number of cases, when less than 30, by the formula $r^2 = 1 - (1 - r^2)\frac{N-1}{N-2}$.

†Standard error.
‡An average of the analyses of the several samples on each sampling date constituted a case. A total of 35 samples were analyzed.

A highly significant negative relationship existed between percentage aggregates >0.1 mm in size and H-ion concentration (correlation coefficient value of $-.853 \pm .0786$).

Any direct effect of the $Al_2(SO_4)_3$ treatment on the state of dispersion of the silt and clay is not evident since the check plat with no treatment and one plat with only limestone added showed the same linear relationship between soil reaction and state of aggregation as was found in the other plats.

DEGREE OF AGGREGATION AND SOLUBLE ALUMINUM

It is highly probable that the properties of Ca-ion saturation and soil reaction have only secondary influences and some other factor or combination of factors is dominantly responsible for the development of a soil structure which would be resistant to the eroding action of water. Recognizing the heterogeneity of soils in their natural state, it is only reasonable to conclude that the formation of stable aggregates in various soils under field conditions is a very complex process. The close association found between degree of acidity and the state of dispersion of the silt and clay in this soil suggests that some property closely associated with soil reaction might be a dominant factor in producing water-stable aggregates. Sideri (17) studying clay-humus formations states, "The elimination of iron and aluminum oxides from the surface of clay particles increases the ability of these particles to aggregate." He believed that the presence of large amounts of these oxides destroyed the orienting properties of clay with respect to humus, resulting in mere coagulation. Whether the quantities of aluminum brought into solution at the acidity of these soils would be sufficient to have an appreciable effect on aggregate formation is not known. However, there is no particular reason to assume that the quantity of aluminum (30 to 100 p.p.m.) removed by a sodium acetate extraction is all of that fraction which might affect the formation of aggregates. The curve showing the relation between acidity and soluble aluminum in Fig. 4 is in accordance with the relationship between these properties reported by Pettinger (14). He showed that large quantities of aluminum come into solution below pH 4.8 and above pH 7.5 with a critical point on the curve above neutrality at about pH 8.5.

The relation between soluble aluminum and aggregation of silt and clay is shown to be high by the correlation coefficient of $-.883 \pm .0638$. This value is not significantly different from the coefficient ($-.895 \pm$

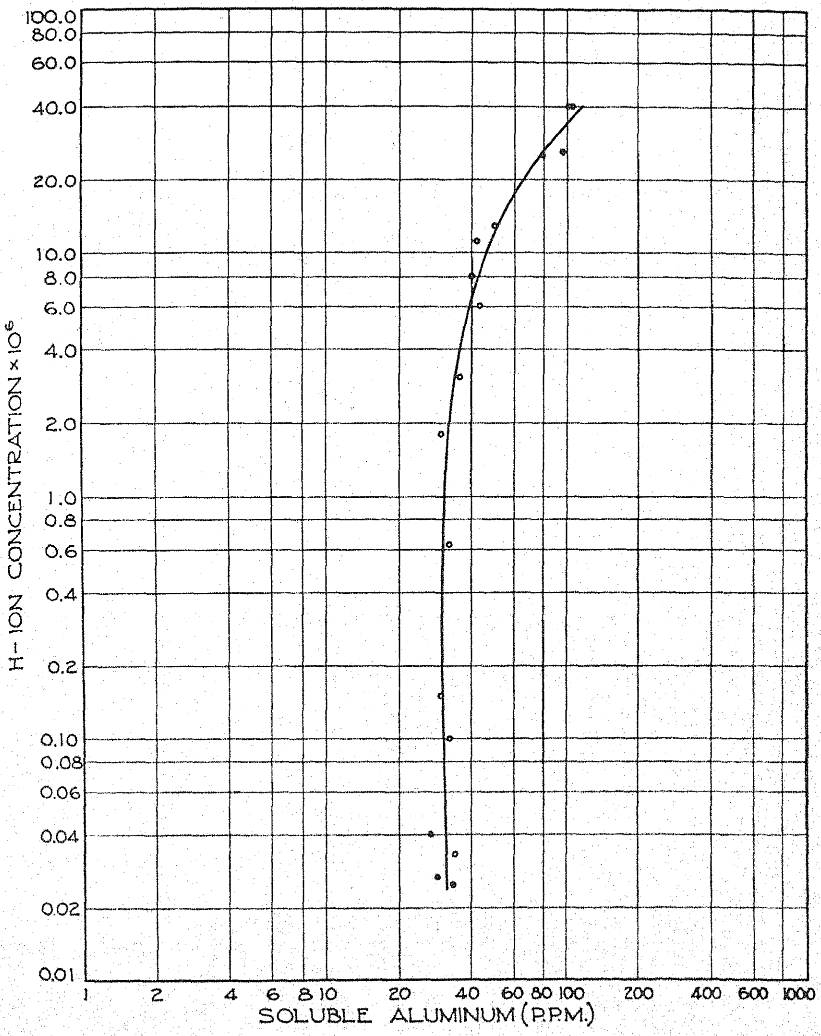

FIG. 4.—Relation of H-ion concentration to soluble aluminum. This graph was adapted from published (16) and unpublished data by G. M. Shear.

$.0576$) expressing the relationship between degree of aggregation and H-ion concentration. The highest pH obtained in this study (7.41) was not sufficiently alkaline to bring large quantities of aluminum into solution above neutrality.

DEGREE OF AGGREGATION AND ORGANIC MATTER

The value of organic matter in improving soil structure has been stressed by many workers and unquestionably the physical condition of some soils is greatly benefited by the addition of organic materials. In the case of this Clarksville loam soil, however, there was no significant relation between total organic matter and the extent of aggregation. This does not preclude the possibility of a relation between the humus content and aggregate formation.

SUMMARY

In a series of plats of Clarksville loam, ranging in pH from 4.45 to 7.41, a close correlation was observed between erodibility and soil reaction. These field observations were substantiated by a laboratory study of the soil. A highly significant negative correlation was found between degree of aggregation and H-ion concentration. Two entirely different procedures were employed for measuring the aggregate condition of the soil and both methods showed this relationship to exist between extent of aggregation and soil reaction.

Increasing quantities of soluble aluminum were accompanied by decreasing quantities of silt and clay aggregated into units larger than silt size. No significant relationship existed between total organic matter and degree of aggregation or observed erodibility.

The addition of ground limestone to Clarksville loam up to the quantity required to produce a neutral reaction definitely improved the physical condition of the soil and its resistance to erosion.

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LINKAGE RELATIONS BETWEEN SMUT RESISTANCE AND SEMISTERILITY IN MAIZE[1]

Chas. R. Burnham and J. L. Cartledge[2]

EARLIER studies by Immer (18)[3] and Hoover (17) on the inheritance of smut resistance in maize made use of certain genetic markers to test for possible linkages. In many cases the associations found were with characters of a morphological type which might conceivably offer extremely favorable conditions for smut infection as, for example, brachytic, liguleless, tassel seed, and ramosa.

In order to study the factors which normally differentiate smut resistant from smut susceptible strains of maize, the present work, using chromosomal interchanges as genetic markers, was undertaken. Interchanges in heterozygous condition appear to bring about no change in morphology other than the abortion of about 50% of both ovules and pollen. The physiological conditions in such semisterile plants may differ from those in the normal plants, but it was hoped that this would not be sufficient to give false evidence of linkage.

MATERIAL

Three smut-resistant lines were available, derived, one each, from the Reid Yellow Dent, Boone County White, and Lancaster Surecrop varieties inbred at the West Virginia Experiment Station for 12 to 14 generations. For most of the work the Lancaster Surecrop line was used since it was most resistant, only one smutted plant having been found since it was first isolated. In a few cases the Boone County White and the Reid Yellow Dent resistant lines were used also. For the susceptible strain a Leaming line inbred over the same length of time was selected, since it was highly susceptible to infection in all portions of the plant.

For the chromosome markers, a series of interchanges was selected from those available from Anderson's study of x-ray induced interchanges (1), and those which had occurred naturally (4, 6, 7). Several were selected involving each chromosome, wherever possible with breaks so located that linkage might be detected under ordinary conditions over the entire length of the chromosome. A list of the interchanges used, together with available information on the positions

[1]Contribution from the Department of Agronomy and Genetics, West Virginia Agricultural Experiment Station, Morgantown, W. Va. Also presented at the annual meeting of the Society, Washington, D. C., November 16, 1938. Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 221. Received for publication August 26, 1939.

[2]Formerly Associate Geneticist at the West Virginia Agricultural Experiment Station and Agent of the U. S. Dept. of Agriculture, Division of Cereal Crops and Diseases, and Assistant Professor of Genetics, West Virginia Agricultural Experiment Station, respectively.

We wish to express our appreciation to Dr. R. J. Garber for crosses involving his long-time inbred smut reaction lines and certain of the chromosomal interchanges and for his continued interest as the study progressed and to C. T. Thorniley for most of the pollen classification. We wish to thank Dr. E. G. Anderson not only for furnishing us with the greater part of the interchanges used, but also for supplying his unpublished cytogenetic data which appear in Table 1 of this publication. The senior author wishes to acknowledge that the final analysis of the data and his part in the preparation of this paper were completed at the Minnesota Agricultural Experiment Station.

[3]Figures in parenthesis refer to "Literature Cited", p. 933.

of the breaks in the chromosomes and in the linkage maps is given in Table 1. A cytological locus listed as 0.7 in the long arm means that the break is at a locus 0.7 of the distance from the spindle fiber to the end of the long arm. We are indebted to Dr. E. G. Anderson for furnishing the unpublished data on his interchanges indicated in the table.

TABLE 1.—*List of chromosomal interchanges used, together with cytogenetic data on the positions of the breaks.*

Interchange	Positions of breaks in chromosomes		Data source	Positions of break loci (T) in corresponding genetic maps		Data source
1-2a	1L.7[1]	2L.6	(13)	f T-3-an	l g v-13-T	(5)
‡1-2c	1 S.7	2L.3	†	T-sr P	—	†
‡1-6a	1L.13	6L.43	(6,13)	T-13-br f	Y Pl-8-T	(6)
‡1-9b	1L.6	9L.5	(2)	br±7	c wx-38-T	(2)
1-9c	1 S.6	9L.2	(2)	near P	c wx-13-T	(2)
1-10a	1L.4	—	†	near br	T-15-g R	†
*2-3a	2 S.9	3L.6	(13)	lg <1	na-10-T-21-a	(13)
2-4c	—	4S	(13)[2]	v-T-Ch	near su	†
*2-4d	—	4L	(13)[2]	B-18-T-6-v	close to Tu	†
‡2-6a	2L.4	6S.0+	(13)	lg B-30-T	Y-2-T-6-Pl	(13)
*3-5a	—	—	—	close to na	T-40-bm-pr	(13)
3-5c	—	—	—	na-12-T-13-a	near pr	†
*3-7b	—	—	—	d±0.4	near ra	†
‡3-8a	3L.6	8L.8	(3)	na-T-ts	T-7-ms j	(3)
3-8b	3L.1	8L.2	(3)	—	T-33-ms j	(3)
*3-10a	3L.1	10L.1	†	ts±10	T-15-g R	†
4-5c	4 S	—	(13)[2]	near su	bm-16-T-3-pr	(†, 13)
4-5d	4 S	—	(13)[2]	near su	near bm	(†, 13)
*4-9a	4L.1	9L.8	(2)	su±(2 or 21)	c wx-(12 or 31)-T	(2)
5-7a	5L.8	7L.7	(11)	bm pr-15-T-14-v	ra ij-11-T	(11)
5-7b	5L.2	7 S.4	(13)	bm-7-T pr	T-11-ra gl	(13)
5-9a	5L.7	9 S.0+	(12)	pr-22-T-6-v	c wx-<1-T	(12)
‡6-8a	6L.5	8L.7	(3)	near Pl	T-8-ms j	(3)
6-10a	6L.7	10L.1	†	Pl sm-22-T	T-10-g R	†
8-9a	8L.2	9L.4	(10)	T-28-ms j	sh wx-14-T	(10)
9-10a	9L.3	10L.9	†	c wx-4-T	g R-5-T	†

[1]Chromosome 1, break in long arm 0.7 of distance from spindle fiber to end of that arm.
[2]Based on cytogenetic data on 4-5a and 4-5b.
†Anderson's unpublished data.
‡Highly significant odds.
*Significant but lower odds.

In Fig. 1 is a summary of the loci on the cytological map. In several instances where only genetic data were available, estimates of the loci have been made based on combined cytogenetic information from other interchanges which were not used in these smut studies, and consequently are not listed. The cytological loci are expected to be accurate only within limits. More accurate placing of the loci requires extensive study of each to determine the frequency of variation in the position of the cross-shaped synaptic figure in heterozygous individuals (10). Detailed study of certain of them had been completed but was not undertaken for each of the others for this smut study.

METHODS

The chromosomal interchange lines were expected to be relatively susceptible since they were from unselected material. The previous work of Hoover (17) had indicated that under the conditions at this station resistance was at least partially

dominant. Accordingly, for the linkage tests the interchanges were crossed with smut-resistant lines and in several cases also with the susceptible Leaming line. Both F_1's were backcrossed to the same susceptible Leaming line. These backcross progenies segregate semisterile plants (heterozygous for the interchange) and normal plants (not carrying the interchange) in a 1:1 ratio; and where the parents differed in smut reaction should also segregate for smut resistance.

In order to study further the behavior of resistance in crosses, progenies from selfing the interchange×resistant F_1, and from backcrossing it to the resistant line were grown.

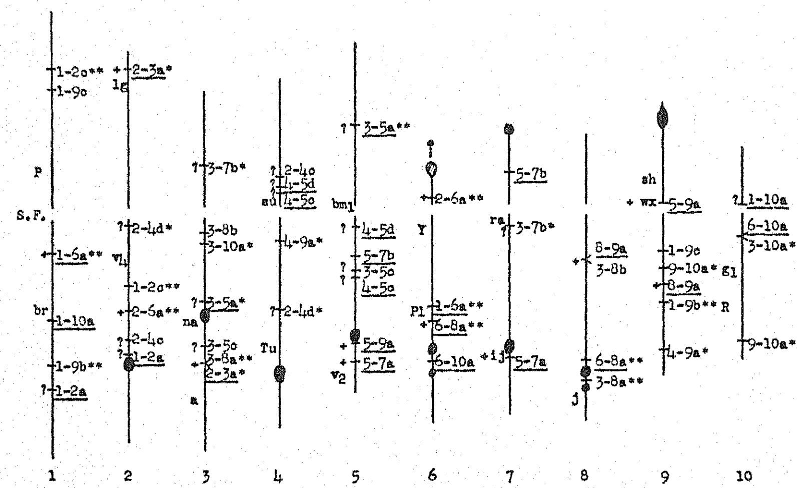

FIG. 1.—Chromosome map of maize showing the loci of interchanges used in the smut study. Those underlined were tested in backcrosses to susceptible of both the (interchange×resistant) F_1 and the (interchange×susceptible) F_1. All the others were tested in backcrosses of only the (interchange× resistant) F_1.

Key to symbols: + opposite a locus means good cytological and genetic data; ? opposite a locus means meager cytologic evidence or only genetic data; none opposite a locus means incompletely summarized cytologic and genetic data; ** gave odds of 99:1 or better indicating linkage between smut reaction and the interchange; * gave low but significant odds indicating linkage.

To give a more uniform opportunity for smut infection, smut spores from boils collected from all parts of smutted plants the previous season were mixed with rotted manure and the mixture allowed to stand in piles for four to five days before spreading between the corn rows. At least three applications of this mixture were made at 10-day intervals after the plants were about 18 inches high. The susceptible and resistant checks were repeated at regular intervals in the field and in the 1938 trial, where possible, single rows of each backcross were replicated and scattered at random in the test plat.

Every fifth plant was tagged and numbered in the field. At the pollen-shedding stage, a tassel branch from each plant was collected and preserved for later pollen sterility classification. Later in the season smut records on each plant were taken, final ear smut notes being taken when the plants were completely matured.

A significant difference in the percentage of smutted plants in the normal and semisterile classes is an indication of linkage between either or both interchange points and a gene or genes for smut reaction. In the progeny of the F_1 (interchange ×resistant) backcrossed to susceptible, such a linkage would result in a higher percentage of smutted plants in the semisterile class than in the normal class, since the original interchange parent was susceptible. Final analysis was made by using Fisher's X^2 test of association for a 2×2 classification involving two different character pairs, the simplified formula being: $X^2 = \frac{(ad-bc)^2 N}{(a+b)\ (c+d)\ (a+c)\ (b+d)}$, entering the X^2 table with one degree of freedom (15). Corrections were made for discontinuity only for those cases in which the P values were near the borderline of significance, or where the numbers were small (16).

RESULTS

In Table 2 is a general summary showing the results from different kinds of crosses and the reaction of the resistant and susceptible parental lines. The same interchanges were not involved in the entire series of crosses, but data from a series involving the same interchanges show relatively the same results. The F_1 of susceptible Leaming×resistant Lancaster was not grown nor were adequate data on the interchange parents obtained. The 1936 results for the different crosses are considered first. The F_1 of susceptible interchange× resistant Lancaster is slightly less resistant than the resistant line itself, with 2.40% of smutted plants as compared with 0%.

TABLE 2.—*Percentages of smut observed in resistant and susceptible inbred lines and in F_1, F_2, and backcrosses involving chromosomal interchange lines, smut plat, West Virginia Experiment Station, 1936, 1937, and 1938.*

Lines	1936		1937		1938	
	Total population	% smut	Total population	% smut	Total population	% smut
Interchange×Leaming susc. F_1	449	36.75	—	—	—	—
Interchange×Lancaster Res. F_1	466	2.40	816	1.96	—	—
Interchange×Boone Co. Res. F_1	138	5.07	—	—	—	—
Interchange×Reid Res. F_1	61	8.20	—	—	—	—
(Interchange×Res.)×Res.	255	3.92	—	—	—	—
(Interchange×Res.) selfed	345	2.90	607	3.79	188	4.79
(Interchange×Res.)×Leam. Susc.	3,078	19.98	5,348	24.93	6,123	24.15
(Interchange×Susc.)×Leam. Susc.	1,017	47.69	—	—	—	—
Leaming Susc. Check	865	37.20	275	50.55	249	54.22
Lancaster Surecrop Res.	64	0.00	142	0.00	79	0.00
Boone County White Res.	74	0.00	123	1.63	81	1.23

This F_1 when backcrossed to the resistant parent showed 3.92% of smutted plants; when backcrossed to the susceptible parent the progeny contained 19.98% of smutted plants. The F_1 of interchange× susceptible Leaming was as susceptible as the susceptible Leaming parent, 36.75% as compared with 37.20%. From the above results

it may be concluded that smut resistance in the Lancaster resistant line is at least partially dominant and that under the conditions at this station the backcross to the susceptible parent is the better one to use for a study of segregation for smut reaction factors.

Data were obtained in 1936, 1937, and 1938 from backcrosses to the susceptible parent, a summary being given in Table 3. Backcrosses in which there was some evidence of linkage in the first tests were repeated the next year along with new backcrosses. In Table 3 are given the numbers of smutted and normal plants, the percentages of smutted plants in the semisterile and in the normal classes, the total population for each, and the X^2 and P values for the tests of association between semisterility and smut reaction. It will be noted in Table 2 that a high percentage of the plants in the susceptible check escaped infection and that the percentage of smutted plants in this line was much higher in 1937 and in 1938 than in 1936. Values of P that are 0.05 or smaller are usually accepted as indicating significant deviations from a random distribution, 0.05 corresponding to odds of 19:1. The following interchanges, double starred on the map in Fig. 1, had P values corresponding to odds equal to or greater than 99:1, the deviations being in the direction expected from linkage with smut resistance: 1–2c, 1–6a, 1–9b, 2–6a, 3–8a, and 6–8a. The others that had significant but low odds, single starred in Fig. 1, were: 2–3a (23:1 odds); 2–4d (24:1); 3–5a (63:1); 3–7b (29:1); 3–10a (24:1); 4–9a (21:1); and 9–10a (66:1).

Since an interchange involves an exchange of pieces between two non-homologous chromosomes, the linkage obtained is in each case evidence for the location of smut reaction factors in either or both chromosomes, that is, near either or both loci at which the original interchange breaks occurred. To determine which of these three possibilities is true a test must be made for each of the two loci with an additional interchange involving a break at nearly the same locus in one of the chromosomes, the other break in this additional interchange being in a third or different chromosome. This latter break locus may need to be checked in the same manner with still another interchange. For example, there is some evidence (odds 24:1) that 3–10a is linked with smut susceptibility. The locus of the 3–10a break in chromosome 3 is checked in a similar linkage test of a 3–8b interchange whose break in 3 is near that of 3–10a in 3. The 3–10a break in 10 is checked similarly by data from a 6–10a interchange whose break in 10 is near that of 3–10a in 10. The locus of 3–8b in 8 and the locus of 6–10a in 6 may then need to be checked by still other interchanges. Since the original interchange stocks might also be carrying factors for smut resistance, one method of study is to cross each interchange with both the resistant Lancaster and the susceptible Leaming lines; backcrossing both F_1's to the susceptible Leaming line. Negative evidence for association from only the F_1 of interchange×resistant does not eliminate the possibility that the interchange line was carrying the same smut resistance factor or factors in its interchanged chromosomes as was the inbred resistant line in its normal homologues. For only 13 of the interchanges are both kinds of backcross tests available, underlined in Fig. 1. In those backcrosses

TABLE 3.—*Summary of data on the progeny from the (interchange × Lancaster resistant) F_1 when backcrossed to the Leaming susceptible line, grown in the smut plat, West Virginia Experiment Station, 1936, 1937, and 1938.*

F_1 cross	Year tested	Normal		Semisterile		Total population	Normal class % smutted	Semisterile class % smutted	X^2	P
		Smutted	Not smutted	Smutted	Not smutted					
1–2a×Res.	'36	57	215	55	198	525	19.91	20.44	0.048	.80
1–2c×Res.	'37, '38	53	261	91	257	662	16.88	26.15	8.334	<.01‡
1–6a×Res.	'36, '37, '38	143	625	238	639	1,645	18.62	27.14	16.694	<.01‡
1–9b×Res.	'37, '38	148	377	193	311	1,029	28.19	38.29	11.846	<.01‡
1–9c×L. S. Res	8	10	38	17	34	99	20.83	33.33	1.948	.2
1–10a×Res.	6, 8	68	216	75	279	638	23.94	21.19	0.689	.3
2–3a×Res.	6, 7, 8	133	699	147	585	1,564	15.99	20.08	4.172[1]	.04*
2–4c×L. S. Res.	8	15	43	11	33	102	25.86	25.00	0.010	.9
2–4d×Res.	7, 8	88	265	117	247	717	24.93	32.14	4.221[1]	.04*
2–6a×Res.	6, 8	55	228	96	184	563	19.43	34.29	15.816	<.01‡
3–5a×Res.	6, 7, 8	45	149	75	142	411	23.20	34.56	5.863[1]	.016*
3–5c×L. S. Res.	7, 8	58	309	78	289	734	15.80	21.25	3.258[1]	.07
3–7b×Res.	7, 8	51	167	44	83	345	23.39	34.65	4.543[1]	.03*
3–8a×Res.	7, 8	210	602	250	488	1,550	25.86	33.88	11.895	<.01‡
3–10a×Res.	7, 8	87	321	124	325	857	21.32	27.62	4.229[1]	.04*
4–5c×L. S. Res.	6	18	77	27	110	232	18.95	19.71	0.021	.9
4–5d×L. S. Res.	6	2	22	2	19	45	8.33	9.52	0.020	.9
(4–5d×L.S. Res.)(×)	7	3	210	5	196	414	14.08	24.88	0.636	.5
4–9a×Res.	7, 8	66	237	88	213	604	21.78	29.24	4.033[1]	.045*
5–7a×L. S. Res.	6	12	83	17	84	196	12.63	16.83	0.685	.5
5–7b×L. S. Res.	8	14	51	6	51	122	21.54	10.53	2.687	.1
5–9a×Res.	6, 8	39	118	32	96	285	24.84	25.00	0.001	.98
6–8a×Res.	6, 7, 8	46	393	108	322	869	10.48	25.12	31.922	<.01‡
6–10a×Res.	6, 8	27	157	22	149	355	14.67	12.87	0.244	.7
8–9a×L. S. Res.	6	10	67	12	50	139	12.99	19.35	1.045	.3
9–10a×L. S. Res.	8	2	70	7	32	111	2.78	17.95	5.911[1]	.015*

[1]Corrected for discontinuity on the total populations.
‡Highly significant odds.
*Significant but lower odds.

using the F_1 of (interchange×susceptible) the populations were small, although there was a high incidence of smutted plants. Although none of the 13 interchanges gave any indication of carrying a factor for resistance which was linked with the interchange, it cannot be concluded that this applies to all interchanges in these studies. Unfortunately both kinds of backcrosses were not tested for all the interchanges used.

An analysis of the results follows, considering the interchanges for which the odds indicate probable linkage and in each case the negative results which have a bearing on the conclusions.

For interchange 1–2c the odds are greater than 99:1. Since T1–9c, whose locus in chromosome 1 is near that of 1–2c, shows negative results, the locus of T1–2c in chromosome 2 is probably the one responsible for the linkage, although the population for T1–9c was small.

Interchange 1–6a also had odds greater than 99:1. Its locus in 1 was not checked, but its locus in 6 is near that of 6–8a which also showed high odds. Hence the locus of 1–6a in 6 and possibly in 1 may be responsible for the linkage.

Interchange 1–9b had odds greater than 99:1. Its locus in 9 is near that of 8–9a for which there was no evidence of linkage in both kinds of backcrosses. Had these been based on adequate numbers, they would indicate the locus of 1–9b in 1 is responsible for the linkage. The locus of 1–2a in 1 is given in Fig. 1 as being near that of 1–9b, but it is not placed there with certainty. Hence the negative results with 1–2a may not conflict with this conclusion.

Interchange 2–3a showed odds of only 24:1. Its locus in 2 was not checked while its locus in 3 is near that of T3–8a for which there was evidence of linkage. If the linkage exists, either that in 3 or both loci in T2–3a may be associated with smut reaction.

For interchange 2–6a the odds were greater than 99:1. Its locus in 2 is near that of 1–2c for which the evidence is positive. It is also near those of both 2–4c and 1–2a in 2, both of which showed negative evidence, although their loci in 2 are not certainly placed. This region in 2 probably contains smut reaction factors. The locus of 2–6a in 6 was not checked. Hence this locus in 6 may or may not be involved also in the linkage.

For interchange 3–8a association was indicated by high odds. Its locus in 3 is near that of 2–3a which also had positive evidence of linkage and also is near that of 3–5c which showed negative evidence but is not certainly placed. The locus of 3–8a in 8 is near that of 6–8a for which there was also good evidence of linkage. Therefore, either or both loci in 3–8a may be responsible for the linkage.

Interchange 3–10a had low odds for association. Its locus in 3 was checked by 3–8b and its locus in 10 by 6–10a both of which gave negative evidence but are based on small populations. If the linkage with 3–10a exists, one possible explanation is that either 3–8b or 6–10a carries the same smut resistance factor as does the resistant line and hence would have shown the linkage only in the backcrossed interchange×susceptible F_1 which was not tested.

For interchange 6–8a there were high odds. Each locus is near that of a second interchange which also had high odds indicating linkage. Since no locus in either of these was eliminated, either or both loci in 6–8a may be associated with smut reaction.

For interchange 9–10a the odds were significant, but the evidence is based on a small population. If the linkage exists, the locus in chromosome 10 must be involved since its locus in 9 is near that of 8–9a for which the results were negative.

For 2–4d (24:1 odds), 3–5a (63:1), 3–7b (29:1), and 4–9a (21:1) none of the break loci was checked for linkage with smut resistance with another interchange. For the first three interchanges, however, the loci are not placed with certainty. If linkage exists, either or both loci may be involved if their positions in Fig. 1 are approximately correct.

Eight of the interchanges that showed negative results in the progeny from backcrossing the F_1 of (interchange×resistant) also showed negative results in backcrosses of the F_1 of (interchange×susceptible). These double tests indicate regions in chromosomes 1, 2, 4, 6, 7, 8, 9, and 10 and a considerable part of the long arm of 5 which do not carry smut reaction factors (Fig. 1) differentiating the resistant and susceptible lines used in these studies.

DISCUSSION

In several cases, a locus that appears to be relatively close on the map to a locus not showing linkage, may be too far away to show linkage with smut reaction. The reasons for this will be apparent from what follows. Evidence on genetic length and corresponding cytologic length is available for the short arm of chromosome 9. Cytogenetic evidence indicates the gene waxy is in the short arm (12) probably near the spindle fiber. The genetic length from the terminal knob to waxy corresponding to most of the short arm is 53.5 units according to the Cornell linkage summary (14). Although this cytogenetic length may not be applicable directly to the other chromosomes, it gives an indication of what physical length may correspond to about 50 units.

The genetic length which a given interchange will test for the presence of smut reaction factors depends on (a) the degree of reduction in crossing over in the presence of the interchange in heterozygous condition and (b) the relative amounts of smut shown in the different homozygous and heterozygous genotypes for the different smut factors. In the susceptible Leaming inbred line, which with its long period of inbreeding should have been relatively homozygous for smut reaction factors, an average of more than 50% of the plants escaped infection. In a segregating progeny these cannot be distinguished from genotypically resistant plants. The evidence from the linkage tests indicates that several factors must be concerned in smut resistance. If these were all of equal value in their reaction to infection, a case of close linkage should give a greater difference, spoken of below as "relative difference", between the percentages of smutted plants in the semisterile and in the normal classes, than should a case of loose linkage. This would be modified if several pairs of smut fac-

tors were involved and if they were unequal in smut reaction value; that is, if comparable genotypes for different pairs of alleles differ in their reaction to smut infection. In this case, the "relative differences" in percentages of smut for interchanges involving different chromosomes would depend on the particular smut reaction alleles involved as well as the strength of linkage. In the data presented here the "relative differences" in percentages of smutted plants vary from 4 to 15 with different interchanges.

Immer (18) obtained positive evidence for the association of smut reaction with the pericarp factor *P*. The trials in the present paper involve different material and therefore not necessarily the same factors for smut reaction. They do not eliminate the possibility that in this material also there may be a smut reaction factor in the region near the locus of 1–6a in 1.

In addition to linkages that might be termed "morphological associations", Hoover (17) obtained linkage between smut reaction and su, v_2, sh wx in crosses with certain inbred lines and not with other inbred lines; the inbred lines differing as to the region of the plant in which most of the smut boils were located. This problem of the factors involved in the localization of smut boils is one which needs further study.

USES OF INTERCHANGES AND INVERSIONS AS GENETIC TOOLS

In this smut study, the interchanges were crossed with each of two pure lines which differed in smut reaction, one resistant, the other susceptible. Without previous information on inheritance, semisterile F_1 plants in each of these crosses would then be backcrossed to each of the two smut reaction lines for a study of segregation of smut reaction in relation to semisterility. A more satisfactory method would have been to make the genetic backgrounds of all the interchanges being used more comparable by backcrossing each F_1 to the original inbred smut reaction line for 5 or 6 generations.

Inversions which give considerable sterility in the pollen when heterozygous may be used in the same manner as the interchanges and may be even more useful since each would test the presence of factors on only one chromosome.

In addition to their use for genetic studies of a problem such as disease resistance, interchanges, and inversions should be useful additional tools for genetic studies of earliness and many quantitative characters.

If the partial sterility affects ears and pollen, the study of a character such as yield is complicated by the fact that such plants do not yield as much grain as do normal sibs. Preliminary data indicate that although half the grains are missing on a semisterile ear, the yield of shelled corn is not decreased proportionately. Weights and kernel counts taken on a series of paired normal and semisterile plants show that on the semisterile ears the grains are significantly heavier than the grains on comparable normal ears.

SUMMARY

Crosses between susceptible chromosomal interchange lines and a resistant Lancaster Surecrop inbred line were backcrossed to a sucseptible Leaming inbred to study segregation for smut reaction in relation to the interchange points.

Highly significant deviations (odds 99:1 or greater) from randomness were obtained, the deviations being in the direction expected with linkage between smut resistance and the following interchanges: 1–2c, 1–6a, 1–9b, 2–6a, 3–8a, and 6–8a. Less significant deviations (odds not less than 19:1) but in the same direction were obtained for 2–3a, 2–4d, 3–5a, 3–7b, 3–10a, 4–9a, and 9–10a.

Of these interchanges, incomplete evidence indicates the locus of 1–2c in chromosome 2 is one of the loci showing linkage with smut reaction. In all other cases, the break locus in either, or the loci in both chromosomes involved in the interchanges listed above may be associated with smut resistance.

The method of procedure in the use of interchanges and inversions for this and other multiple factor problems has been considered.

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SYMBIOTIC PROMISCUITY OF TWO SPECIES OF CROTALARIA[1]

J. K. WILSON[2]

DURING the past 50 years many phases of the relationships existing between the legume bacteria and the leguminous plants have been studied. One of these which has stimulated much research because of its practical application is the degree of specificity ascribed to members of a certain genus towards strains of the Rhizobia. An illustration of this is provided by the clover plant-bacteria group in which species of trifolium only are listed. The group was established from experimental evidence which indicated that the species of the Rhizobium for this genus is specific. Similar relationships are ascribed to other genera and to specific organisms that bear definite names for these genera. Thus, the species of the bacteria for the clover group is *Rhizobium trifolii*, that for the alfalfa group, *Rh. meliloti*, and so on to the extent of the groups. With this classification, if a species or strain of the bacteria from one group should be found, for one reason or another, to associate with a species of plant from another plant-bacteria group, it might be described at one time as *Rh. trifolii* and at another time as *Rh. meliloti*, or it might bear various names, depending on the source from which it came.

Several investigators have observed that a strain of the Rhizobium from a certain plant that has been placed in a plant-bacteria group is not so specific as the group would indicate. Some workers have dismissed such data on the grounds of faulty technic, but recently Wilson (1)[3] reopened this question and reported many such irregularities. He (2) was unable to find an organism that was specific for a group of plants or for one plant. Among other things, he (1) also found that *Crotalaria verrucosa* nodulated with only 3 of 32 strains, while *C. grantiana* nodulated with 29 of the same 32 strains. These 29 strains were isolated from plants representing about 10 plant-bacteria groups and from plants that have not been placed in any group.

Wilson (1) emphasized further that several species of Crotolaria and species of other genera are more promiscuous in their relations with strains of the rhizobia than others; *Amorpha fruticosa* L., *Medicago sativa* L., *Phaseolus coccineus* L., *Robinia pseudoacacia* L., and others being promiscuous, and *Cicer arietenum* L., *Ornithopus sativus* Bort., *Psoralea onobrychis* Nutt., and many others being restricted.

Such data suggest that a single strain may be encountered in the nodules of numerous legumes irrespective of the plant-bacteria group or groups to which the legumes may have been assigned. In this connection numerous instances were reported by Wilson in which a strain from a plant appeared equally well or better adapted to other species, irrespective of the plant bacteria groups, than it was to the plant from which it was isolated. It appears, therefore, if a number of

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[2]Soil Bacteriologist.
[3]Figures in parenthesis refer to "Literature Cited", p. 939.

strains of the rhizobia from a large number of genera or from a plant like *Amorpha fruticosa* that is promiscuous were tested in this regard, that valuable information bearing on several phases of the relationships existing between the legume bacteria and the leguminous plants may be obtained. It is the purpose of this paper, therefore, to record the symbiotic promiscuity of *Crotalaria grantiana* Harvey and *C. verrucosa* L. with 182 isolations of the rhizobia which were obtained from a wide selection of legumes and to emphasize their relations to the established plant-bacteria groups.

METHODS

The method employed in a piece of work will influence the strength of the conclusions that can be drawn. For this reason, if confidence in the results is invited, the selection of a method is highly important. In this case it should provide surroundings in which the symbionts can be housed together during the growing period to the exclusion of interfering organisms and maintain satisfactory growing conditions. Such a method was described by Wilson (1) and was followed in executing the experiments reported in this paper.

Seeds of both species of Crotalaria were planted in containers plugged with cotton and grown simultaneously so that each species was exposed to the same isolations of the Rhizobium and to the same light, heat, and variations that normally occur in a greenhouse. Because the supply of seeds of both species of Crotalaria was limited only 10 to 12 or so were planted in each container. It might have been better to have had a larger number of plants in each test for Wilson (1) pointed out that the occurrence of nodules on plantlets of *Medicago sativa* and on plantlets of other species may not be observed with a small number of plants when employing certain strains of the rhizobia but might be if a larger number of plants are grown for examination.

The cultures of the organism used represent isolations from 71 species and varieties, representing 46 genera, one of which was not identified. Each isolation was known to effect symbiosis from tests with appropriate seedlings, employing these same methods. Certain isolations may be identical, especially those from a definite source, although the isolations from *Amorpha fruticosa* are known to be extremely dissimilar in many cases (Wilson, 2). Part of the work was repeated as many as four times, a part only two or three times, and, in a few cases, individual tests were made.

DATA

The data are given in summary form in Table 1. They show that both species of Crotalaria are promiscuous in their relations with strains of the Rhizobia and that *C. grantiana* is more promiscuous than is *C. verrucosa*. The former bore nodules with 137 of the 182 isolations, while the latter bore nodules with only 41 of the same isolations. Among these isolations were 52 from *Amorpha fruticosa* L. With 42 of these *C. grantiana* bore nodules and with 17 of the 52 *C. verrucosa* bore nodules. In every case when *C. verrucosa* bore nodules with these isolations from *A. fruticosa*, *C. grantiana* also bore nodules with the corresponding isolations. In no case did *C. verrucosa* bear nodules with an isolation from *A. fruticosa* that failed to nodulate with *C. grantiana*. In some cases when both species bore nodules with the same strain one species might be strongly nodulated while the

other might be weakly nodulated. It is evident, therefore, that both species of Crotalaria are not equally suited to bear nodules with the same isolation or with isolations from an identical source.

TABLE 1.—*Summary of data, showing symbiotic promiscuity of two species of Crotalaria with isolations of Rhizobium from numerous species of legumes.*

Sources of isolations	Number of isolations	Number symbiosing with	
		C. grantiana	*C. verrucosa*
Amorpha fruticosa	52	42	18
Astragalus menziesii	3	2	0
Astragalus rubyi	4	4	1
Daubentonia drummondii	3	3	1
Lotus corniculatus	8	5	0
Lotus scoparium	2	2	0
Medicago sativa	11	7	3
Robinia pseudoacacia	4	4	0
Trifolium pratense	9	8	0
Trifolium repens	3	3	0
Vicia villosa	12	12	0
All other species	71	45	18
Total	182	137	41

Among those isolations tested on both species of Crotalaria are three from *Astragalus menziesii* A. Gray and four from *A. rubyi*. *C. grantiana* bore nodules with all isolations except one from *A. menziesii*, while *C. verrucosa* bore nodules with only one and that one was an isolation from *A. rubyi*. Also, there were three isolations from *Daubentonia drummondii* Rydb. *C. grantiana* bore nodules with each isolation, while *C. verrucosa* bore nodules with only one of them. In this case nodulation was excellent. *C. grantiana* also bore excellent nodules with this isolation. In addition, *C. grantiana* nodulated with isolations from *Lespedeza hirta* (L.) Hornem, *L. procumbens* Michx., *L. striata* Hook & Arn, and *L. violaceae* (L.) Pers., while *C. verrucosa* nodulated with isolations from the first and last species only. Further, there were eight isolations from *Lotus corniculatus* L. and two from *L. scoparium*. *C. grantiana* bore nodules with five of the eight strains and with both strains from *L. scoparium*, while *C. verrucosa* bore no nodules at all with any one of the 10 isolations.

There were 11 isolations of Rhizobium from *Medicago sativa* L. *C. grantiana* bore nodules with seven of these, while *C. verrucosa* bore nodules with only three of the 11. In no case, with either species of Crotalaria, were the plants excellently nodulated.

When nine isolations of Rhizobium from *Trifolium pratense* L. were employed, *C. grantiana* bore nodules with eight of the isolations, while *C. verrucosa* bore no nodules with the same isolations. When three isolations from *T. repens* L. were employed, *C. grantiana* bore nodules with each isolation, while *C. verrucosa* failed to nodulate with the same isolations. When the isolations from *T. incarnatum* L. and from *T. suaveolens* Willd. were employed, *C. grantiana* bore nodules but *C. verrucosa* did not. When the isolations from *T. johnstonii* and

from *T. subterraneum* were employed, neither species of Crotalaria bore nodules.

In addition, *C. grantiana* bore nodules when grown in association with other isolations, while *C. verrucosa* did not. The sources of these were *Albizzia julibrissin* Biov. (Durazinni), one of two isolations; *Amphicarpa monoica* (L.) Ell.; *Apios tuberosa* Moench; *Aspalanthus sarcodes* Vog. et Walp.; *Coronilla varia* L.; *Crotalaria spectabiles* Roth.; *Dalea alopecuroides* Willd., one of three isolations; *Indigofera viscosa* Lam., one of two isolations; *Glycine max* (L.) Meer.; *Mimosa pudica* L.; *Parosela scoparia* (A. Gray) Heller., one of three isolations; *Oxytropis lambertii* Pursh., one of two isolations; *Petalostemon purpurea* (Vent.) Rydb.; *Prosopis juliflora* DC.; *Robinia pseudoacacia*, four isolations; *Rynchosia minima* (L.) DC.; two of three isolations; *Sutherlandia frutescens* R. Br.; *Tephrosia grandiflora* Pers.; *Vicia villosa* Roth, 12 isolations; *V. atropurpuria* Desf.; *V. disperma* DC.; *V. villosa* Roth var. Gore; and an unidentified species.

Further, both species of Crotalaria bore nodules when grown in association with isolations from the following plants: *Acacia constricta* Benth.; *Albizzia julibrissin*, one of two isolations; *Crotalaria sagittalis* L.; *Cassia chamaecrista* L., one of two isolations; *Dalea alopecuroides*, two of three isolations; Desmodium canadense (L.) DC., one of two isolations; *Sesbania macrocarpa* Mahl.; *Stizolobium deeringianum* Brot.; *Sutherlandia frutescens*, one of two isolations; and *Swainsonia coronillaefolia* Salisb.

Also, both species of crotalaria failed to bear nodules when grown in association with isolations from the following plants: *Baptisia australis* R. Br.; *Caragana frutescens* DC.; *Cassia chamaecrista*, one of two isolations; *Cicer arietinum* L., two isolations; *Desmodium canadense*, one of two isolations; *Droycnium herbaceum* Vill.; *Laburnum vulgaris* Gris.; *Lens esculenta* Moench.; *Lupinus sp.*; *L. perennis* L.; *Onobrychis viciaefolia* Scop.; *Ononis vaginalis* Vahl.; *Oxytropis lambertii; Parosella scoparia*, two of three isolations; *Phaseolus vulgaris* L.; *Spartium scoparium* L.; *Strophostyles helvola* (L.) Britton; *Tephrosia virginianum* (L.) Pers.; *Thermopsis caroliniana* M.A. Curt.; and *Vigna sinensis* Endl.

It was observed also that *C. verrucosa* bore nodules when grown in association with the isolation from *Phaseolus polystachyus* (L.) B. P., while *C. grantiana* did not.

SIGNIFICANT FACTS IN THE FINDINGS

Certain significant points in the data should be emphasized. One of these relates to the placing of *C. grantiana* and *C. verrucosa* in a plant-bacteria group. If the bearing of nodules by a plant when grown in association with an isolation of the rhizobia is the criterion for placing a plant in any one of the plant-bacteria groups, then these two species can be placed in any one of several groups depending upon the particular isolation that was employed in making the tests. When employing a certain isolation both species might be placed with *Amorpha fruticosa*, when employing another isolation *C. grantiana* might be placed with *A. fruticosa* while *C. verrucosa* might not be placed with either. If still another isolation was employed, neither

species would be placed with *A. fruticosa*. It is clear, therefore, that the particular isolation will determine the placing of a plant in any group or in no group.

If this method of procedure is followed, *C. grantiana* can be placed in at least 10 of the plant-bacteria groups and *C. verrucosa* in four. If enough isolations were tested, it should be suspected that both species might be placed in still more groups. As suggested by Wilson (2) this means that a strain is not specific and that it may be found at one time in the nodules of one plant representing one plant bacteria group and at another time in the nodules of another plant representing still another group or another genus.

It should be emphasized also that *C. grantiana* is decidedly more promiscuous in its relations with the various isolations of the rhizobia than is *C. verrucosa*, for as stated above the data show that *C. grantiana* bore nodules with 137 of the 182 isolations while *C. verrucosa* bore nodules with only 41 of the same isolations. This indicates that, although plants may belong to a certain genus, there is no necessary connection between this and their relations with the various strains.

Wilson (1) pointed out in studying 19 species of Crotalaria that *C. grantiana* was the most promiscuous while *C. verrucosa* was the most restricted. The other 17 species which came between these extremes also exhibited no detectable relationship between the fact that they belong to a single genus and their relations with strains of the rhizobia which came from a definite genus or from a definite source. Wilson (3) also pointed out that this promiscuity is closely associated with the degree of cross-pollination of the species. Plants that are obligatorily cross-pollinated or depend on insects to effect pollination are the most promiscuous. If this is true then the boundaries surrounding every species must be as irregular as the mixing of characters through cross-pollination from year to year would indicate. Under these conditions the boundaries surrounding highly self-fertilizing plants are more regular than those surrounding highly cross-pollinating plants. This might indicate that *C. grantiana* is highly cross-pollinating and *C. verrucosa* highly self-pollinating, although no data are available bearing on the degree of selfing or crossing of these two species of Crotalaria.

Some emphasis should be placed on the fact that each species of Crotalaria was not equally suited to bear nodules with the same strain. If nodulation was weak on *C. grantiana* when employing a certain strain, it was absent in numerous instances on *C. verrucosa*. This was observed in 53 instances. In about 50% of the cases when nodulation was good on *C. grantiana* it was weak on *C. verrucosa*. Whether this condition is native to the species or to the bacteria is unknown. It may be due somewhat to the environmental condition under which the plantlets were grown.

DISCUSSION AND CONCLUSION

The data presented in this paper substantiate and extend those recently published by Wilson (1). In his work he employed isolations from most of the plant-bacteria groups and was unable to place

Crotalaria grantiana and *C. verrucosa*, as well as many other plants, in any group. In the present work 182 isolations were employed and were obtained from plants representative of each plant-bacteria group and from many species that have not been placed in any group or possibly from which isolations have never been made. The same type of promiscuity was observed with these 182 isolations as that which was observed by Wilson. With these conditions existing it was impossible to assign either species to a plant-bacteria group.

From the evidence presented it seems that the particular isolation employed in making the tests will determine whether a species is placed in this or that group. This is taken to mean that the plant-bacteria groups as now recognized are entirely inadequate. If one attempts to use such groups and is unable to place a species in just one group, it is difficult to come to any other conclusion. The plant-bacteria groups may have some practical value, but when the data presented here are considered in connection with those previously published, it is obvious that from the scientific standpoint the plant-bacteria groups should be abandoned.

If promiscuity between the various strains of the rhizobia and certain species of legumes is as widespread as the data show, then it is evident, as stated above, that a strain may be found at one time in the nodules of a plant from one plant-bacteria group and at another time in the nodules of a plant from a different plant-bacteria group. Therefore, at one time a strain may bear the name *Rhizobium meliloti* and at another time *Rh. trifolii*. In this connection *Crotalaria grantiana* bore nodules with organisms from 11 of the plant-bacteria groups and with organisms from 14 species of legumes that have not been included in any group. Also *C. verrucosa* bore nodules with organisms from four of the plant-bacteria groups and with organisms from eight species that have not been included in any group.

It is perfectly logical, therefore, if the proposed method of naming an organism is followed, that any strain of the rhizobia may be given different names at different times or by different workers depending upon the source from which it was obtained. This is another reason for abandoning the plant-bacteria groups. Such findings may also partly explain some of the apparent contradictions in the literature concerning the morphology and the physiology of strains from a certain species, especially species that are highly promiscuous.

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AVAILABILITY, FIXATION, AND LIBERATION OF POTASSIUM IN HIGH-LIME SOILS[1]

HUBERT ALLAWAY AND W. H. PIERRE[2]

MANY small areas of high-lime soils occurring in that part of Iowa covered by the Wisconsin drift have been found to produce very poor crops. Corn grown on these areas shows a marginal "firing" or dying of the leaves and is often a complete failure, whereas on the surrounding soil it normally produces over 50 bushels per acre. Although it has been found that the application of potassium fertilizers to these soils will bring about large increases in crop yields, relatively little information is available upon which to base a satisfactory explanation of these facts.

These high-lime soils occupy naturally poorly drained sites and commonly contain as much as 25% calcium and magnesium carbonate. Since the areas are relatively small, usually varying in size from a few square rods to several acres, they have not been shown in the county soil survey maps but have been included with soils of the Webster series with which they are associated.

The problem of improving the high-lime soils of Iowa was recognized in 1915 by Stevenson and Brown (18).[3] At that time these soils were called "alkali" soils and an excess of soluble salts was considered to be responsible for their low productivity.

In 1918 Bancroft (2) differentiated these high-lime soils from the arid alkali soils of Wyoming and attributed their low productivity to the high concentration of calcium carbonate and bicarbonate.

Stevenson, Brown, and Boatman (19) reported results of fertilizer experiments on high-lime soils in 1926. A profitable response to potassium fertilization was shown in several cases.

Kilpatrick (11) concluded from more recent field experiments that unproductive high-lime soils will produce as good yields as the rest of the field if they are fertilized with from 100 to 500 pounds of potassium chloride per acre. The beneficial effects of this treatment seem to disappear, however, within two or three years after the application.

Dean (7) found 12 high-lime soils from Iowa to be high in total potassium, but 11 of the 12 were low in available potassium as measured by the *Aspergillus niger* method. Four of the 11 were low and the other 7 were slightly low according to standards set up by the authors of the method.

Sears (17) attributed the low productivity of the high-lime soils of Illinois to low available potassium and unusually high nitrate content. One of these soils which responded to potassium fertilization was found to be low in exchangeable potassium. He presents some evidence that rapid fixation of added potassium may contribute to the low level of available potassium.

McGeorge (13) studies the availability of potassium in the calcareous soils of Arizona. He found that although these soils were low in water-soluble potassium, they were relatively high in exchangeable potassium and did not show immediate

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[3]Figures in parenthesis refer to "Literature Cited", p. 953.

need for potassium fertilization. From this work it is evident that the calcareous soils of Arizona differ from the soils studied by Dean and Sears.

In recent years considerable information has been published concerning the availability of the exchangeable and non-exchangeable potassium and the factors which affect the relative amounts of these forms of potassium in the soil. Several investigators (12, 21, 23) have demonstrated that fixation of potassium in a non-exchangeable form is an important factor in determining the fertility of soils. It has also been shown (1, 4, 9, 10, 16) that the non-exchangeable potassium of the soil may be liberated fast enough to make an important contribution to the supply of potassium available to plants. However, very little data of this type have been obtained for high-lime soils.

The objectives of the study reported here were (a) to determine the amounts of exchangeable potassium in unproductive high-lime soils and to determine whether or not the poor corn growth on these soils as compared to the good growth on adjacent soils can be explained on the basis of differences in exchangeable potassium; and (b) to determine whether the marked response to potassium fertilizers on unproductive high-lime soils and the relatively small residual effects from large potassium applications can be explained by a high potassium fixing power or a relatively slow liberation of potassium from the non-exchangeable to the exchangeable form.

SOILS STUDIED AND METHODS USED

In July, 1938, samples of soil were taken from high-lime spots in nine different corn fields in north central Iowa. In six of these fields demonstrations of the effect of potassium fertilizers were being carried on by the Iowa Agricultural Extension Service and marked responses to applications of potassium fertilizer were being obtained. Soil samples were taken from unfertilized areas where the corn showed marked symptoms of potassium deficiency, namely, marginal firing of the leaves and stunted growth. Samples were also taken from unfertilized areas a short distance away where the corn appeared to be growing normally. In several instances, two samples of soil were taken from the area which was supporting good crop growth, and in one case two samples of the unproductive soil were obtained. In all fields the sample from the area of normal plant growth was taken less than 100 feet away from the area on which plants showed marked symptoms of potassium deficiency. Each sample was a composite of ten borings. All samples were taken at two depths, *viz.*, 0–6 inches and 6–12 inches. In no case was there an appreciable difference in the appearance of the soil at the two depths.

The demonstrations carried on by the Extension Service furnished some general information on the yields of the unproductive spots and the response of these areas to potassium fertilization.

The exchangeable potassium was extracted by leaching 10 grams of soil with 250 cc of normal ammonium acetate. The leachate was evaporated to dryness, treated with a 6% solution of hydrogen peroxide in order to destroy the organic matter, and the ammonia driven off. Potassium was determined in an aliquot representing 2 grams of soil by the method of Brown, Robinson, and Browning (5). This method was modified to include two washings of the precipitate with 70% alcohol instead of the single washing. This method was found to extract practically all of the exchangeable potassium and to give reproducible results and satisfactory recovery of potassium from standard solutions.

Organic carbon was determined by the method of Walkley and Black (24).

Carbonate determinations were made by digesting 0.5 to 2.0 grams of soil with standard hydrochloric acid. The soil was then placed on a filter and the excess hydrochloric acid was washed out with barium chloride. The filtrate and washings were then titrated with standard sodium hydroxide, using methyl red as the indicator.

In determining the potassium-fixing power of the soil 3 cc of a standard potassium chloride solution were added to 10 grams of air-dry soil. The concentration of the solution used was such that this amount of potassium was equivalent to an application of 252 pounds per 2,000,000 pounds of soil. The samples were then placed in a saturated atmosphere for 24 hours, after which the water-soluble and exchangeable potassium were determined by the same method used for the untreated soil. The amount of potassium fixed by the soil was obtained by subtracting the amount found from the sum of the original exchangeable potassium content of the soil and the amount added.

The rate at which potassium is liberated from the non-exchangeable form was determined by exhausting the soil of exchangeable potassium and then incubating it for 80 days at 30% moisture. At the end of this time the exchangeable potassium was determined and the amount found was considered to have been liberated from the non-exchangeable form. The removal of the exchangeable potassium at the start of the experiment was accomplished by leaching the soil with normal ammonium acetate. This was followed by a leaching with calcium acetate to restore the colloid to nearly its original condition in regard to calcium saturation. The excess calcium acetate was washed out with water before incubation.

RESULTS

FIELD OBSERVATIONS AND DATA

The description of the plants at the time of sampling the soil and the yields and responses to potassium fertilization on the unproductive areas are shown in Table 1. Fig. 1 shows the appearance of the corn on the untreated and fertilized plats in the Carlson field. Since the yield data in Table 1 represent the results from only one year, and since the plats were established as demonstration rather than on an experimental basis, the data must be regarded as only approximations. However, the beneficial effect of potassium fertilization is definitely demonstrated.

EXCHANGEABLE POTASSIUM AND OTHER CHEMICAL DATA

The exchangeable potassium, calcium carbonate, and organic matter contents of the unproductive high-lime soils and the adjacent soils which supported good crop growth are shown in Table 2.

In every case it was found that the unproductive soils contained less exchangeable potassium than the soils from the same fields which supported good corn growth, the values being 31 to 743% greater in the latter. The same general relation held true for the second 6-inch layers, although in samples from the Barnes and Bennett fields the 6- to 12-inch layer of the productive soil was also quite low in exchangeable potassium. The first 6 inches of the unproductive soils contained an average of 151 pounds of exchangeable potassium per 2 million pounds of soil, whereas the productive soils averaged

396 pounds. Based on the average of the first and second 6 inches, 9 of the 10 unproductive soils contained less than 175 pounds of potassium per 2 million pounds of soil, whereas 10 of the 12 soils which were supporting normal crop growth contained more than this amount.

The unproductive soils generally contained more calcium carbonate than did the productive soils from the same field. The average amount of calcium carbonate in the top 6-inch layer of the soils on which corn

FIG. 1.—Response of corn to potassium fertilizer on high-lime soils in the Carlson Field, 1938. Fertilizer was applied along the row with fertilizer attachment to cultivator approximately six weeks after planting. (Four rows per plat.)

showed deficiency symptoms was 24.0% as compared with only 12.5% in the productive soils. In some cases there was very little difference in the calcium carbonate content of the productive and unproductive soils. Eight of the 10 soils on which the plants showed deficiency symptoms contained more than 15% calcium carbonate, whereas 8 of the 12 soils on which normal corn growth was found contained less than this amount.

The organic carbon content of all the soils was high, ranging from 4.8 to 8.8%. There was no consistent relation between organic matter content and growth of the corn.

TABLE 1.—*Location of samples, description of plants, yields, and responses to potassium fertilization.**

Soil sample No.	Description of plants at time of sampling soil, July 15–16, 1938	Yield of corn on untreated area, bu. per acre	Response to fertilization
	Patterson Field (Hamilton Co.)		
1	Marked deficiency symptoms; good response to potassium fertilization	45.4	74% from 125 lbs. of 0–20–10 per a
2	Corn normal, about 4½ feet high, 60 feet from sample 1		
	Nolte Field (Wright Co.)		
3	Marked deficiency symptoms; good response to fertilization; corn about 1 foot high	30.7	95% from 200 lbs. KCl per acre 77% from 100 lbs. KCl per acre
4	Corn apparently normal, 4 to 5 feet high		
5	Very good corn growth; 80 feet from sample 3		
	DeWolf Field (Pocahontas Co.)		
6	Deficiency symptoms; corn 2½ feet high; good response to fertilization	42.5	42% from 200 lbs. KCl per acre 10% from 100 lbs. KCl per acre
7	Normal corn growth, about 5 feet high; 50 to 70 feet from sample 6	82.1	
8	Normal corn, about 5 feet high		
	Carlson Field (Pocahontas Co.)		
9	Marked deficiency symptoms, 1 to 2 feet high; good response to fertilization	6.7	930% from 500 lbs. KCl per acre 728% from 200 lbs. KCl per acre
10	Normal corn, 5 to 6 feet high; 20 feet from sample 9		
11	Vigorous corn growth, 6 to 6½ feet high		
	Barnes Field (Palo Alto Co.)		
12	Marked deficiency symptoms		
13	Normal corn growth, about 5 feet high		
	Conway Field (Palo Alto Co.)		
14	Deficiency symptoms; some response to fertilization	60.0	23% from 200 lbs. KCl per acre 26% from 100 lbs. KCl per acre
15	Marked deficiency symptoms; 25 to 30 feet from sample 14		
16	Normal corn, about 5 feet high; 50 feet from sample 15		
	Vaudt Field (Kossuth Co.)		
17	Marked deficiency symptoms; good response to potassium fertilization	25.0	188% from 200 lbs. KCl per acre 151% from 100 lbs. KCl per acre
18	Normal corn 5 to 6 feet high; 60 to 70 feet from sample 17		
	Bennett Field (Story Co.)		
19	Normal corn about 4 feet high; 40 to 50 feet from sample 20	63.4	
20	Marked symptoms of potassium deficiency	43.2	
	Erickson Field (Story Co.)		
21	Marked symptoms of potassium deficiency	50.6	
22	Normal corn 4 to 5 feet high; 40 to 50 feet from sample 21	54.3	

*Since plats were not replicated, yield and response data are only approximations.

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TABLE 2.—*The exchangeable potassium, calcium carbonate, and organic carbon content of soils from unproductive areas and from adjoining areas of normal crop growth.*

Sample No.	Description of plants in July	Depth of soil samples, inches	Exchangeable potassium, lbs. per acre*	$CaCO_3$ %	Organic carbon %
		Patterson Field			
1	Deficiency symptoms	0–6 6–12	205 143	26.0 17.4	7.9
2	Normal growth	0–6 6–12	381 287	9.2 3.6	5.7
		Nolte Field			
3	Deficiency symptoms	0–6 6–12	148 123	18.7 6.0	6.9
4	Normal growth	0–6 6–12	196 169	18.0 17.6	7.8
5	Normal growth	0–6 6–12	273 277	2.5 1.8	5.1
		DeWolf Field			
6	Deficiency symptoms	0–6 6–12	148 128	20.8 22.7	5.5
7	Normal growth	0–6 6–12	401 376	21.4 23.1	6.4
8	Normal growth	0–6 6–12	317 291	3.2 3.0	4.0
		Carlson Field			
9	Deficiency symptoms	0–6 6–12	162 87	21.7 22.5	5.1
10	Normal growth	0–6 6–12	952 789	11.6 13.7	5.9
11	Normal growth	0–6 6–12	1,780 1,759	16.2 22.8	7.3
		Barnes Field			
12	Deficiency symptoms	0–6 6–12	85 78	27.6 39.5	6.7
13	Normal growth	0–6 6–12	185 84	25.5 34.2	7.3
		Conway Field			
14	Deficiency symptoms	0–6 6–12	189 96	30.7 34.8	8.6
15	Deficiency symptoms	0–6 6–12	164 53	32.6 41.9	8.8
16	Normal growth	0–6 6–12	392 210	12.8 11.3	7.0

TABLE 2.—*Concluded.*

Sample No.	Description of plants in July	Depth of soil samples, inches	Exchangeable potassium, lbs. per acre*	$CaCO_3$ %	Organic carbon %
			Vaudte Field		
17	Deficiency symptoms	0–6 6–12	195 171	13.4 12.0	5.6
			Whittemore Field		
18	Normal growth	0–6 6–12	278 241	9.4 8.2	5.6
			Bennett Field		
19	Normal growth	0–6 6–12	178 97	12.6 11.3	4.3
20	Deficiency symptoms	0–6 6–12	136 68	35.6 33.8	5.2
			Erickson Field		
21	Deficiency symptoms	0–6 6–12	107 98	20.6 13.4	4.7
22	Normal growth	0–6 6–12	189 175	6.4 2.5	6.8
			Average†		
	Deficiency symptoms	0–6	151	24.0	6.1
	Normal growth	0–6	396	12.5	6.2

*Calculated on basis of 2,000,000 pounds of soil per acre 6⅔ inches.
†When two samples of soil showing the same type of plant growth were taken from one field, the analyses of the two samples were averaged and considered as one figure in computing the average for all fields.

POTASSIUM FIXATION STUDIES

The results of the study on potassium fixation are shown in Table 3. In every case the unproductive soil fixed more potassium than the productive soil from the same field, the average fixation being 211 pounds of potassium per 2 million pounds of soil for the former and only 105 pounds for the latter. One of the unproductive soils, number 3A, fixed all of the potassium added and 71 pounds per acre of potassium which was originally exchangeable, a total fixation of 323 pounds. The lowest amount of potassium fixed by any unproductive soil was 111 pounds per acre. Sample 11A, which supported normal corn growth, not only showed no potassium fixation but released 88 pounds of potassium per 2 million pounds of soil during the time that it was allowed to stand in a moist condition.

The potassium-fixing power of 10 non-calcareous soils, which represent some of the more extensive soil types in Iowa, was determined by the same methods as were used on the soils from fields containing un-

TABLE 3.—*Potassium fixation by productive and unproductive high-lime soils.**

Sample No.	Nature of soil	Original exchangeable K, lbs. per acre	K fixed, lbs. per acre
		Patterson Field	
1A	Unproductive	205	194
2A	Productive	381	161
		Nolte Field	
3A	Unproductive	148	323
4A	Productive	196	171
5A	Productive	273	157
		DeWolf Field	
6A	Unproductive	148	265
7A	Productive	401	141
8A	Productive	317	213
		Carlson Field	
9A	Unproductive	162	230
10A	Productive	952	49
11A	Productive	1,780	88†
		Barnes Field	
12A	Unproductive	85	228
13A	Productive	185	123
		Conway Field	
14A	Unproductive	189	151
15A	Unproductive	164	170
16A	Productive	392	90
		Vaudte Field	
17A	Unproductive	195	182
18A	Productive	278	120
		Bennett Field	
19A	Productive	178	56
20A	Unproductive	136	111
		Erickson Field	
21A	Unproductive	107	205
22A	Productive	189	75
		Average	
	Unproductive	151	211
	Productive	396	105

*Calculated on basis of 2,000,000 pounds of soil per acre 6⅔ inches.
†Released rather than fixed.

productive high-lime areas. The original content of exchangeable potassium and the potassium-fixing power of these soils are given in Table 4. It is evident from the data that the non-calcareous soils fixed very little potassium, the average fixation for the 10 soils being only 13 pounds per 2 million pounds of soil.

TABLE 4.—*Potassium fixation by acid upland soils.*

Soil type	Soil group	Original exchangeable potassium, lbs. per acre	Potassium fixed, lbs. per acre*
Tama silt loam	Normal Prairie	638	−82
Edina silt loam	Planosol	179	24
Grundy silt loam	Planosol	429	24
Tama silt loam	Normal Prairie	660	6
Clarion loam	Young Prairie	366	47
Marshall silt loam	Normal Prairie	527	− 5
Marshall silt loam	Normal Prairie	1,114	10
Fayette silt loam	Gray Brown Podzolic	140	52
Clinton silt loam	Gray Brown Podzolic	283	44
Carrington loam	Normal Prairie	191	11
Average		453	13

*The amount of potassium chloride added to the soils was equivalent to 252 pounds of potassium per acre (2,000,000 lbs. soil).

STUDIES ON POTASSIUM LIBERATION

The results of the study on the liberation of potassium from the non-exchangeable form are shown in Table 5. As previously stated, the exchangeable potassium was removed from these soils before incubating them for 80 days at 30% moisture. The amount of exchangeable potassium found at the end of the incubation period, therefore, represents the amount liberated from non-exchangeable form. The amounts thus obtained ranged from 45 to 117 pounds of potassium per acre. In four of the five fields studied the productive soils liberated more potassium than the unproductive soils. The differences, however, are not great. One acid soil, the Edina silt loam, liberated about the same amount of potassium as most of the calcareous soils.

The fertilized soils that had received 850 pounds of potassium in the form of potassium chloride in growing two crops of corn released considerably higher amounts of potassium during the 80 days incubation period than the unfertilized soils. The actual differences are low, however, when compared with the large amounts added, corroborating the fact that these soils possess a high fixing power for potassium.

GENERAL DISCUSSION

The data given in Table 2 indicate that the differences in plant growth on the unproductive high-lime areas as compared to that on the adjacent soils may be due, at least partly, to differences in the

amounts of exchangeable potassium present. This is emphasized by the fact that the productive soils contained an average of 151% more exchangeable potassium than the unproductive soil from the same field.

TABLE 5.—*Potassium released from soils in 80 days following removal of the exchangeable potassium, expressed as pounds per acre.**

Field	Sample No.	Nature of soil	Original amount of exchange-able K	K released
DeWolf	6A	Unproductive	148	52
	8A	Productive	317	69
Barnes	12A	Unproductive	85	65
	13A	Productive	185	79
Vaudt	17A	Unproductive	195	64
	18A	Productive	278	78
Nolte	G1†	Unproductive	138	60
	G2	Productive	250	54
	G1	Unproductive, fertilized	294	87
	G2	Productive, fertilized	441	67
Carlson	G3	Unproductive	180	45
	G4	Productive	440	70
	G3	Unproductive, fertilized	399	113
	G4	Productive, fertilized	841	117
Edina		Planosol	179	72
Average		Unproductive, unfertilized	149	57
		Productive, unfertilized	294	70

*Calculated on basis of 2,000,000 pounds soil per acre 6⅔ inches.
†The prefix G shows that the soils had been used in plant response studies in the greenhouse. The fertilized pots received a total of 850 pounds of potassium per acre in the form of potassium chloride. The two plantings of corn on these pots were harvested after 30 and 36 days, respectively.

When comparisons are made of soils from different fields, however, it becomes evident that certain of the soils which supported normal corn growth were lower in exchangeable potassium than some of the unproductive soils from other fields. It is apparent, therefore, that in addition to the actual amount of exchangeable potassium present other factors influence the response of plants to potassium fertilization on these soils. One of these factors may be the calcium-potassium ratio in the soil solution, for various workers have pointed out that excessive amounts of available calcium may exert a depressive effect upon the absorption of potassium by plants (8, 9, 14, 20).

Sears (17) found that the unproductive high-lime soils of Illinois contained excessively high amounts of nitrates and concluded that this was partially responsible for the low productivity of these soils. Since these soils contained large amounts of calcium carbonate, it is quite likely that the nitrates were present as calcium nitrate. Thus, a high concentration of nitrates would mean a large amount of soluble calcium and a wide calcium-potassium ratio in the soil solution, a condition that would decrease the absorption of potassium by plants.

A number of investigators have studied the amount of potassium necessary for good crop growth. Bray (3) concluded that soils that contain 140 pounds or more of exchangeable potassium per acre in the surface 6⅔ inches will give good crop growth on well-managed corn belt soils, that soils containing from 90 to 140 pounds will probably respond to potassium fertilization, and that those below 90 pounds will show good responses to potassium fertilization.

Volk and Truog (21) place the dividing line between potassium deficient soils and those not deficient at about 165 pounds of exchangeable potassium per acre.

Murphy (15) states that soils of Oklahoma which contain more than 120 pounds of exchangeable potassium per acre will usually support good crop growth, although occasional responses to potassium fertilization may be obtained on soils containing up to 200 pounds per acre.

As shown in Table 2, corn made very poor growth and showed signs of extreme potassium deficiency on some of the high-lime soils of this study, even though they contained from 140 to 200 pounds of exchangeable potassium per 2,000,000 pounds of surface soil. Since the investigations of Bray, Volk and Truog, and Murphy indicate that soils with this amount of exchangeable potassium should be only slightly deficient, it is evident that more exchangeable potassium is necessary for good plant growth on high-lime soils than on the normally acid soils of central United States which were studied by these investigators. This difference may likewise be due to calcium-potassium antagonism in high-lime soils.

The unproductive soils generally contained more calcium carbonate than the productive soils from the same field, although some of the productive soils were quite high in calcium carbonate content. This indicates that the calcium carbonate content of these soils is not the controlling factor in determining the productivity of the two types of areas. For example, soils 6 and 7 contained practically the same amounts of carbonate, although the latter produced almost twice as much corn as the former. However, soil 7 contained about three times as much exchangeable potassium as soil 6, which probably accounts for the difference in productivity. The same relationship is shown by comparing soils 3 and 4 and also soils 12 and 13.

The data on potassium fixation indicate that differences in the potassium-fixing power of productive and unproductive soils may account partly for the differences in the amounts of available potassium present and therefore be the underlying cause of potassium deficiency in the former soils. It is of interest to note that the potassium-fixing power of the acid soils was very low in comparison to that of the calcareous soils. This no doubt explains the fact that in field experiments very little residual effects have been observed from heavy broadcast applications of potash fertilizers.

The results of the study on the liberation of potassium from the non-exchangeable form indicate that liberation may be slightly more rapid in the soils which supported good crop growth. The differences, however, do not seem to be large enough to explain the difference in crop growth obtained on the two types of areas.

SUMMARY AND CONCLUSIONS

Unproductive high-lime soils from nine different fields in north central Iowa were compared with soils from the same fields which supported normal crop growth. The results may be summarized as follows:

1. Within any given field the productive soil contained from 31 to over 700% more exchangeable potassium than the unproductive soil. The latter averaged 151 pounds of exchangeable potassium per acre (2 million pounds), whereas the productive soils averaged 396 pounds.

2. Seven of the 10 unproductive soils contained less than 175 pounds of exchangeable potassium per acre, whereas all 12 of the productive soils contained more than this amount.

3. The unproductive soil was generally higher in calcium carbonate than the productive soil from the same field, the average content of the former being 24.0%, and of the latter 12.6%.

4. Eight of the 12 productive soils contained less than 15% calcium carbonate in the surface 6 inches, whereas 9 of the 10 unproductive soils contained more than this amount.

5. In every field, the unproductive soil showed a greater potassium-fixing power than the productive soil. The average amount of potassium fixed by 10 unproductive calcareous soils was 211 pounds per acre, by 12 calcareous productive soils 105 pounds, and by 10 acid soils only 13 pounds.

6. In four out of five fields studied the productive soils showed a more rapid liberation of non-exchangeable potassium, although the differences were relatively small.

From these results it may be concluded that:

1. Differences in the amounts of exchangeable potassium present may account, at least in part, for the differences in plant growth between unproductive high-lime soils and adjacent soils which support normal plant growth.

2. The high-lime soils of Iowa apparently require more exchangeable potassium in order to support good crop growth than do the normally acid soils of central United States.

3. Excessively high concentrations of calcium carbonate and bicarbonate may contribute, either directly or indirectly, to the low productivity of these soils.

4. On the basis of the relatively few soils studied in this investigation, it would appear that soils of north central Iowa which contain more than 15% calcium carbonate and less than 175 pounds of exchangeable potassium per acre will likely show signs of extreme potassium deficiency and respond markedly to potassium fertilization. Some high-lime soils containing more than this amount of exchangeable potassium may also give good response to potassium fertilization.

5. The high potassium-fixing power of unproductive high-lime soils may be responsible for the relatively low amounts of exchangeable potassium in these soils no doubt explains the small residual effects obtained from applications of potassium fertilizers.

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GERMINATION OF THE SEED OF POVERTY GRASS, *DANTHONIA SPICATA*[1]

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POVERTY grass, *Danthonia spicata* (L.) Beauv., is a perennial with rather wide distribution on poor soils throughout the eastern United States. Because of the ability of this grass to grow on poor and eroded soil, it may have some value for erosion control work. Two samples collected in the Shenandoah National Forest by D. W. Levandowsky were submitted by M. M. Hoover of the Soil Conservation Service with the request that experiments be made to determine the germination requirements of this seed. No published information has been found on the germination requirements of *Danthonia spicata*.

The writer will not attempt to review the extensive literature on the occurrence of dormancy of seeds and methods for overcoming dormancy which has been reviewed by Crocker (2, 3),[3] Toole (7), and others.

The greater part of the work on sulfuric acid treatment of seeds deals with cotton and legumes and will not be reviewed here. Burton (1) has recently published on the beneficial effect of treatment with sulfuric acid on several species of southern grasses and found that crude sulfuric acid of approximately 78% strength could be used successfully. Stoddart and Wilkinson (6) showed that the seed of *Oryzopsis hymenoides*, a western grass, is benefitted by treatment with concentrated sulfuric acid, the length of treatment giving best results depending on the size of the seed. Huntamer (4) found a 5-minute treatment with concentrated sulfuric acid beneficial for *O. hymenoides*.

MATERIALS AND METHODS

As stated above, two samples were used in these experiments. Samples No. 1 and No. 2 presumably of 1938 harvest were received on August 29 and December 22, 1938, respectively. Apparently both samples were from the same original bulk, the difference in results with the two samples being due to difference in storage conditions. Sample No. 1 was stored as a small sample in the laboratory during the 4 months that sample No. 2 remained in bulk storage.

The seed as received was cleaned by means of an air blast blower. Both samples contained approximately 77% of heavy caryopses. Only the heavy caryopses were used in this study. The seed was placed for germination in Petri dishes on paper toweling saturated with tap water or with a 0.2% solution of potassium nitrate. Tests were made in duplicate. The seed was germinated at both constant and alternating temperatures. The alternation of temperature was secured by transferring the test from one germination chamber to another, the test remaining

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[2]Junior Botanist. Grateful acknowledgment is made to E. H. Toole for his suggestions and criticisms throughout these investigations, and to V. R. Boswell for his assistance with the statistical analysis.

[3]Figures in parenthesis refer to "Literature Cited", p. 965.

at the first temperature listed for 17 and at the second temperature for 7 hours out of each 24 hours. The temperature of the germination chambers was controlled within 1 degree of that listed. In order to obtain light exposure accompanying a high temperature alternation, the test was placed in a north window of an air-conditioned building for the 17-hour period. The room temperature varied from 16° to 24° C.

To prechill the seed it was placed on moistened paper toweling and held at 3° or at 10° C for various lengths of time. The temperature of the 3° chamber varied between 2° and 5° C. The time of counting is dated from the day the seed was placed to prechill and not from the day the seed was transferred to the germination temperature.

To treat the seed with sulfuric acid, the seed was placed in a small porcelain crucible, covered with an excess of acid, and stirred constantly for the designated time. The treated seed then was washed in running tap water for 30 to 45 minutes and dried thoroughly before placing to germinate. The approximately 71% sulfuric acid used was made by diluting 3 parts of concentrated sulfuric acid (sp. gr. 1.84 and at least 94%) with 1 part distilled water by volume.

The sprouts were counted at regular 7-day intervals. Those seeds were considered as germinated which produced a normally developed seedling.

Germination figures summarized in Tables 1, 3, and 5 are in all cases mean values, based on duplicate tests of 100 seeds each. Values for "error" and tests of significance of differences have been calculated by the analysis of variance method as adapted by Snedecor (5).

PRESENTATION OF RESULTS

The study of various pretreatments with prechilled temperatures and with sulfuric acid, of the effect of potassium nitrate, and of the effect of two germination temperatures on the two samples of seed was broken down for simplification of presentation into Tables 1 to 6, inclusive.

GERMINATION AT VARIOUS TEMPERATURES

Sample No. 1, when first received, was germinated at the constant temperatures of 10°, 15°, 20°, 25°, and 30° C, and at the alternating temperatures of 10° to 25°, 15° to 25°, 20° to 30°, 20° to 35°, and 20° to 40°, each with water and with 0.2% solution of potassium nitrate. Since 15% was the highest germination obtained in 63 days, the data hardly require presentation in tabular form. Prechilling at 3° and at 10° followed by germination at alternating temperatures gave higher results that suggested the value of further work along this line.

PRECHILLING TREATMENT

In January, 1939, seed of sample No. 2 was prechilled at 3° C and at 10° for 14, 21, and 28 days, then germinated at 10° to 25° and at room temperature to 35°, with and without the use of potassium nitrate. The results are given in Table 1 and the analysis of variance is given in Table 2. The mean of all tests prechilled at 3° is significantly better than the mean of all tests prechilled at 10°. There is a significant difference between the two prechilling temperatures when germinated at 10° to 25° and a highly significant difference between

the two prechillings when germinated at room temperature to 35°. Prechilling at 3° is decidedly better than at 10° when germinated at either room temperature to 35° or at 10° to 25° with the use of tap water and at room temperature to 35° with the use of potassium nitrate. The differences in germination among the tests that were prechilled different numbers of days were quite variable, being significant in some cases showing a progressive benefit with longer treatment at the 3° prechilling temperature. Prechilling at 3° for 63 days appears to be the most effective. Greater differences in germination were generally observed among the various times of prechilling than be-

TABLE 1.—*Germination in 119 days of seed of Danthonia spicata (sample No. 2) at indicated temperatures with specified treatment, means of duplicate 100 seed tests.**

Germination temperature, °C	Treatment of medium	Duration of prechilling, days	Percentage germination response to prechilling treatment at: Number of observations	3° C	10° C	Mean: Number of observations	Mean: Germination, %
10° to 25°	Nitrate	14	2	21.5	32.5	4	27.0
		28	2	53.5	41.5	4	47.5
		63	2	87.0	83.5	4	85.25
		Mean	6	54.0	52.5	12	53.25
	Water	14	2	5.0	4.5	4	4.75
		28	2	11.5	5.0	4	8.25
		63	2	76.0	48.0	4	62.00
		Mean	6	30.8	19.1	12	24.9
	Mean	14	4	13.25	18.5	8	15.87
		28	4	32.5	23.25	8	27.87
		63	4	81.5	65.75	8	73.62
		Mean	12	42.4	35.8	24	39.1
Room to 35°	Nitrate	14	2	65.5	59.5	4	62.5
		28	2	79.0	75.0	4	77.0
		63	2	87.0	47.0	4	67.0
		Mean	6	77.1	60.5	12	68.8
	Water	14	2	27.5	35.5	4	31.5
		28	2	62.5	42.0	4	52.25
		63	2	69.0	44.0	4	56.5
		Mean	6	53.0	40.5	12	46.75
	Mean	14	4	46.5	47.5	8	47.00
		28	4	70.75	58.5	8	64.62
		63	4	78.0	45.5	8	61.75
		Mean	12	65.05	50.5	24	57.77

*Minimum differences required for significance are: Between means of 2 observations 30.12%; between means involving 4 observations 12.12%; 6 observations 9.00%; 8 observations 7.50%; 12 observations 5.96%; 16 observations 5.06%; 24 observations 4.05%.

TABLE 1.—*Concluded.*

Germination temperature, °C	Treatment of medium	Duration of prechilling, days	Percentage germination response to prechilling treatment at: Number of observations	3° C	10° C	Mean: Number of observations	Mean: Germination, %
Mean	Nitrate	14	4	43.5	46.0	8	44.75
		28	4	66.25	58.25	8	62.25
		63	4	87.0	65.25	8	76.12
		Mean	12	65.5	56.5	24	61.00
	Water	14	4	16.25	20.0	8	18.12
		28	4	37.0	23.5	8	30.25
		63	4	72.5	46.0	8	59.25
		Mean	12	41.9	29.8	24	35.85
	Mean	14	8	29.87	33.00	16	31.43
		28	8	51.62	40.87	16	46.24
		63	8	79.75	55.62	16	67.68
		Mean	24	53.72	43.16	48	48.43

TABLE 2.—*Analysis of variance of germination data in Table 1.*

Source of variation	Degrees of freedom	Mean square
Total	47	724.08
Prechilled temperatures (3° and 10° C)	1	1,344.08*
Germination temperatures (10–25 and R-35)	1	4,181.33*
Treatments (No. of days prechilled)	2	5,314.77*
Between KNO_3 and H_2O	1	7,600.33*
Prechilled temperatures × germination temperature	1	192.01†
Prechilled temperatures × treatment	2	742.65*
Prechilled temperatures × nitrate	1	27.01†
Germination temperature × treatment	2	2,830.02*
Germination temperature × nitrate	1	114.09†
Treatment × nitrate	2	235.15‡
Prechilled temperature × germination temperature × treatment	2	57.84†
Prechilled temperature × germination temperature × nitrate	1	154.07†
Germination temperature × nitrate × treatment	2	167.64‡
Prechilled temperature × treatment × nitrate	2	13.68†
Prechilled temperature × germination temperature × treatment × nitrate	2	259.74‡
Error	24	49.00

*Variances are highly significant with reference to error.
†Not significant with reference to error.
‡Significant with reference to error.

tween the prechilling temperatures used. The greatest difference in nitrate response was associated with the shorter prechilling periods. The proportional effect of nitrate versus water is approximately the same at both germination temperatures and at the two prechilling temperatures.

TREATMENT WITH CONCENTRATED SULFURIC ACID

Treatment of the seed with concentrated sulfuric acid for 1, 3, and 5 minutes in October, 1938, and then germinating the seed at 10° to 25°, 20° to 30°, and at room temperature to 35° C gave higher results than the check test at the same temperatures. The best results (43% germination) were obtained with a 5-minute acid treatment followed by germination at room temperature to 35°. However, some of the seeds apparently were injured and some still remained sound and ungerminated.

TREATMENT WITH APPROXIMATELY 71% SULFURIC ACID

In January, 1939 at the time the prechilling experiment was conducted, seed from samples Nos. 1 and 2 was also treated with 71% sulfuric acid for 0, 15, 30, and 45 minutes and then germinated at 10° to 25° and at room temperature to 35° C. The tests were in duplicates of 100 seeds each with 0.2% solution of potassium nitrate and with water. The results for the 28 and 119 day counts are given in Table 3, and the analysis of variance in Table 4.

The results of the analysis of variance indicate highly significant differences in germination due to each of the several single factors studied. Nearly all interactions were also significant. The difference in response of the two samples probably was due to the fact that the sample stored in the laboratory for the longer period had dried out more and was therefore more resistant to germination. The room temperature to 35° germination temperature was strikingly better than 10 to 25°. Potassium nitrate induced a higher percentage germination in 28 days at 10° to 25° but not at room temperature to 35°; the increase is generally evident at both temperatures by 119 days. Pretreatment with 71% sulfuric acid for 30 to 45 minutes and then germinating at room temperature to 35° C with the use of potassium nitrate afforded the optimum condition. With sample No. 1, 15 minutes was not long enough acid treatment to give the best results, but longer treatment than 30 minutes did not seem to be necessary. With sample No. 2 there was no significant difference among the three acid treatments when germinated at room temperature to 35°.

As stated above the optimum condition for the germination of this seed requires careful control of not one major factor but of several factors, as shown by the high significance of the interactions involved.

There is a significant difference in the response of the two samples at the two germination temperatures, the greater difference between samples being at 10° to 25° C. This sample difference had decreased by the final count but was still of significance. The difference in response of the two samples to nitrate was somewhat variable and of doubtful importance. At 28 days the samples showed greater variance

in response to the germination temperature than to nitrate, but by the final count at 119 days the variance due to nitrate was greater than that due to the germination temperature. At 28 days the untreated seed were little affected by nitrate, but by 119 days there was a greater effect of nitrate on the untreated samples. The high variance due to acid treatments was brought about mainly by the low value of the zero time treatment.

DOUBLE TREATMENT WITH APPROXIMATELY 71% SULFURIC ACID

The results obtained in the preceding experiment showing approximately 85% germination or better appeared to represent the full value of the sample since the seeds either germinated or decayed. Some of the treated tests resulted in about 10% lower germination with sound seeds remaining at the end of the experiment. The writer thought that perhaps a short time of treatment of the seed with acid, thoroughly washing and drying, and followed by another short period of treatment, thoroughly washing and drying, might give a more uniform response. Treatments of 15 and 15, 15 and 30, 30 and 15, 30 and 30, 45 and 15, and 45 and 30 minutes were tried. The seed was then put to germinate at 10° to 25° and at room temperature to 35° C with and without the use of potassium nitrate. In every case there was decided injury to the seed. Sample No. 1 treated 15 and 15 minutes and tested at room temperature to 35° germinated 34 and 29% with the use of potassium nitrate and water, respectively. Contrast this with the 30-minute treatment shown in Table 3. The longer the period of the two treatments, the greater was the injury to the seed.

ACID TREATMENT VERSUS PRECHILLING

The 45-minute treatment with 71% sulfuric acid and the 3° C prechilling tests were selected for this comparison. There was no significant difference between the prechilled 63-day and the 45-minute acid treatment tests at 10° to 25° with potassium nitrate or with water; at room temperature to 35° there was a significant difference with water but not with potassium nitrate. The 45-minute acid treatment was significantly better than the 14 and 28 days prechilling when germinated at either temperature. The final germination results are given in Table 5 and analysis of the variance of data in Table 6.

PRECHILLING IN ADDITION TO ACID TREATMENT

Seed of the two samples treated with 71% sulfuric acid for 15, 30, and 45 minutes was prechilled at 10° C for 28 days before subjecting them to the germination temperature, room temperature to 35° C.

As shown in Table 3, the acid treatment alone brought about maximum germination in most cases. However, prechilling was of no additional benefit on the 15-minute acid treatment with water that gave incomplete germination of the viable seed. The results are not given in tabular form.

TABLE 3.—*Germination of seed of Danthonia spicata at indicated temperatures after being treated with approximately 71% H_2SO_4 for various times, means of duplicate 100 seed tests.**

Germination temperature, °C	Treatment of medium	Sample No.	No. of observations	Percentage germination response to acid treatment for time shown				Mean	
				None	15 min.	30 min.	45 min.	No. of observations	Germination, %
			28 Days in Germinator						
10° to 25°	Nitrate	1	2	2.0	29.0	35.0	55.0	8	30.25
		2	2	9.5	66.5	57.0	72.0	8	51.25
		Mean	4	5.75	47.75	46.0	63.5	16	40.75
	Water	1	2	3.0	17.5	24.5	44.5	8	22.37
		2	2	6.0	39.5	35.0	63.5	8	36.0
		Mean	4	4.5	28.5	29.75	54.0	16	29.18
	Mean	1	4	2.5	23.25	29.7	49.75	16	26.31
		2	4	7.7	53.0	46.0	67.75	16	43.62
		Mean	8	5.1	38.12	37.85	58.75	32	34.96
Room to 35°	Nitrate	1	2	8.5	64.5	79.0	73.5	8	56.37
		2	2	22.5	82.0	74.0	79.5	8	64.5
		Mean	4	15.5	73.25	76.5	76.5	16	60.43
	Water	1	2	9.0	62.5	80.5	80.5	8	58.12
		2	2	22.0	74.0	72.0	84.0	8	63.0
		Mean	4	15.5	68.25	76.25	82.25	16	60.56
	Mean	1	4	8.75	63.5	79.75	77.0	16	57.24
		2	4	22.25	78.0	73.0	81.75	16	63.75
		Mean	8	15.5	70.75	76.37	79.37	32	60.49
Mean for 28 days			16	10.3	54.43	57.22	69.06		47.72

119 Days in Germinator

10°, to 25°	Nitrate	1	2	34.5	77.5	79.0	81.5	8	68.12
		2	2	32.5	81.5	83.5	83.0	8	70.12
		Mean	4	33.5	79.5	81.25	82.25	16	69.12
	Water	1	2	5.5	29.5	46.0	59.0	8	35.0
		2	2	9.5	55.5	55.5	75.5	8	49.00
		Mean	4	7.5	42.5	50.75	67.25	16	42.0
	Mean	1	4	20.0	53.5	62.5	70.25	16	51.56
		2	4	21.0	68.5	69.5	79.25	16	59.56
		Mean	8	20.5	61.0	66.0	74.75	32	55.56
Room to 35°	Nitrate	1	2	27.5	84.0	88.0	83.5	8	70.75
		2	2	48.0	85.5	89.0	83.5	8	76.5
		Mean	4	37.75	84.75	88.5	83.5	16	73.62
	Water	1	2	12.5	70.0	86.5	84.0	8	63.25
		2	2	25.0	77.5	78.0	86.0	8	66.62
		Mean	4	18.75	73.75	82.25	85.0	16	64.93
	Mean	1	4	20.0	77.0	87.25	83.75	16	67.0
		2	4	36.5	81.5	83.5	84.75	16	71.56
		Mean	8	28.25	79.25	85.37	84.25	32	69.28
Mean for 119 days			16	24.37	70.12	75.68	79.5	64	62.42

*Differences required for significance in the 28-day test between means of two observations 19.44%; between means involving 4 observations 7.82%; 8 observations 4.84%; 16 observations 3.26%; 32 observations 2.26%. Differences required for significance in the 119-day test between means of 2 observations 11.35%; between means involving 4 observations 4.57%; 8 observations 2.83%; 16 observations 1.91%; 32 observations 1.32%.

TABLE 4.—*Analysis of variance of germination data in Table 3.*

Source of variation	Degrees of freedom	28 days mean square*	119 days mean square*
Total	63	801.66	711.23
Temperatures	1	10,429.52	3,011.26
Between KNO_3 and H_2O	1	523.27	5,130.14
Between samples	1	2,268.15	631.26
Between acid treatment	3	10,604.81	10,530.89
Temperature × KNO_3	1	546.39	1,359.77
Temperature × sample	1	467.63	47.27†
Temperature × acid treatment	3	629.72	141.27
KNO_3 × sample	1	112.89†	92.64
KNO_3 × acid treatment	3	117.56	243.89
Sample × acid treatment	3	216.43	55.26
Temperature × KNO_3 × sample	1	17.02‡	206.64
Temperature × KNO_3 × acid	3	48.93‡	75.18
Temperature × sample × acid	3	179.18	160.93
Sample × acid × nitrate	3	22.18‡	60.56
Sample × KNO_3 × acid × temperature	3	9.89‡	100.38
Error	132	20.42	6.98

*Unless otherwise indicated, variances are highly significant with reference to error.
†Significant with reference to error.
‡Not significant with reference to error.

TABLE 5.—*Germination in 119 days of seed of Danthonia spicata (sample No. 2) at the indicated temperatures with specified treatment, means of duplicate 100 seed tests.**

Germition temperature, °C	Treatment of medium	Percentage germination of tests pretreated as shown					Mean	
		No. of observations	Prechilled for 14 days	Prechilled for 28 days	Prechilled for 63 days	Acid 45 min.	No. of observations	Germination, %
10° to 25°	Nitrate	2	21.5	53.5	87.0	83.0	8	61.25
	Water	2	5.0	11.5	76.0	75.0	8	42.00
	Mean	4	13.25	32.5	81.5	79.0	16	51.62
Room to 35°	Nitrate	2	65.5	79.0	87.0	88.5	8	78.7
	Water	2	27.5	62.5	69.0	86.0	8	61.2
	Mean	4	46.5	70.75	78.0	87.25	16	69.95
Mean	Nitrate	4	43.5	66.25	87.0	85.75	16	69.97
	Water	4	16.25	37.00	72.5	80.5	16	51.60
	Mean	8	29.87	51.62	79.75	83.12	32	60.78

*Minimum differences required for significance are: Between means of 2 observations 14.50%; 4 observations 6.60%; 8 observations 3.88%; 16 observations 2.52%; 32 observations 1.71%.

TABLE 6.—*Analysis of variance of germination data in Table 5.*

Source of variation	Degrees of freedom	Mean square*
Total	31	788.93
Temperature	1	2,701.12
Between KNO_3 and H_2O	1	2,701.12
Between treatments	3	4,930.87
Temperature $\times KNO_3$	1	6.14
Temperature $\times$ treatment	3	840.37
$KNO_3 \times$ treatment	3	309.37
Temperature $\times KNO_3 \times$ treatment	3	208.20
Remainder (error)	16	11.37

*All values, except temperature $\times$ KNO_3, are highly significant with reference to error.

WATER ABSORPTION

The seeds remaining sound at the end of the test period were firmer than sound seed remaining in tests of fescue. The sound seeds were more comparable to the few dormant seeds sometimes observed in fresh *Lolium multiflorum* from the West. The question arose as to whether the non-germinating seeds of Danthonia were really impermeable to water. Was the resistance to germination due to lack of water absorption?

A small experiment was set up to determine the amount of water, if any, absorbed by non-treated seed and by acid-treated seed of Danthonia. Because the glumes were removed by the acid treatment, in order to make the tests comparable, the glumes were removed from the untreated lots by a slight pressure with the finger at the base of the caryopsis. After weighing, the seed was immersed in water for 24- and 48-hour periods when weights were again determined. The results are given in Table 7.

TABLE 7.—*Determination by weight of the amount of water absorbed by the seed and glumes of Danthonia spicata.*

Sample No.	Material soaked in water	Acid pretreatment of seed, minutes	Percentage of water taken up in		
			10 minutes	24 hours	48 hours
1	Seed	None	—	30.55	35.91
	Glumes	None	—	53.86	57.87
2	Seed	None	3.11	28.48	35.55
	Glumes	None	45.04	42.54	42.54
2	Seed	15	—	33.09	37.63
2	Seed	30	—	37.45	39.41
2	Seed	45	—	34.93	37.20

The difference in the amount of water absorbed by the treated and untreated seed is slight, although the rate of absorption was somewhat slower in the untreated seed. It would seem probable that the

poor germination without acid or prechilling treatment is due to restrictions of gas exchange instead of, or in addition to, slower water absorption.

DISCUSSION

The poor germination of untreated seed of *Danthonia spicata* would seem to be due to coat restrictions rather than to embryo dormancy, since acid treatment of the seed allowed rather prompt and maximum germination. It is probable that the coats restrict gas exchange, because water absorption was considerable, although slow, with the untreated seeds. The most striking results from the study of the germination requirements of this seed are that, even after acid treatment or prechilling, temperature of germination, possibly light, and previous history of the sample are important factors. There is a high interaction, in many cases, between these factors as shown by the different response of the two samples to nitrate, to germination temperature, and to length of acid treatment, and by the different effect of nitrate depending on germination temperature and length of acid treatment or time of prechilling.

In some instances the effect of certain factors was more pronounced after 119 days germination than after 28 days, while in other instances differences that were evident at 28 days were much less so or had disappeared by 119 days.

SUMMARY

This experiment was planned to find out the conditions necessary for the maximum germination of the seed of poverty grass, *Danthonia spicata*. Two samples of seed collected in the Shenandoah National Forest were used in this study. Tests were run in duplicates of 100 seeds each.

Preliminary experiments with various constant and alternating temperatures revealed that more was involved than the factor of the germination temperature.

The alternating temperature of room temperature to 35° C afforded a better condition for germination than 10° to 25°.

Germination was stimulated by a dilute solution of potassium nitrate.

Prechilling at 3° C for 63 days before placing to germinate at room temperature to 35° or 10° to 25° brought about maximum germination where potassium nitrate was used. Less time of prechilling with potassium nitrate or prechilling with water gave erratic results. Prechilling at 10° was not as good as prechilling at 3°.

Pretreating the seed with 71% sulfuric acid for 30 to 45 minutes was equally as effective as prechilling at 3° C for 63 days and brought about the final results in a shorter time. Pretreating for 15 minutes was not long enough in some instances. Prechilling the seed at 10° in addition to the acid treatment was of no benefit.

Pretreating the seed with concentrated sulfuric acid for 1, 3, and 5 minutes produced injury. Apparently there is a very narrow range for treatment with concentrated sulfuric acid.

Double treatments with 71% sulfuric acid for 15 and 15, 15 and 30, 30 and 15, 30 and 30, 45 and 15, and 45 and 30 minutes caused excessive injury to the seeds and was less effective than the very short treatments with concentrated sulfuric acid.

The sample held in the laboratory for 4 months was more resistant to treatments than the sample recently received from bulk storage.

The seedcoat is not impermeable to water as are the coats of seeds designated as "hard" seeds.

Nontreated seed absorbed water at a slower rate than seeds that had been treated for 15, 30, and 45 minutes with 71% sulfuric acid.

The seedcoat of *Danthonia spicata* is apparently the inhibiting factor in delaying germination, but it seems probable that this is due to restriction of gas exchange since restriction of water absorption is small.

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THE EFFECT OF CALCIUM ARSENATE UPON THE YIELD OF COTTON ON DIFFERENT SOIL TYPES[1]

CLARENCE DORMAN AND RUSSELL COLEMAN[2]

IN recent years the demand for insect control has made it necessary to apply relatively large amounts of arsenates to certain crops. This is particularly true in the South where dusting cotton with calcium arsenate for boll weevil control has become an important practice. Most of the applied arsenic reaches the soil, and some recent investigations have indicated that accumulated arsenic greatly reduces the productivity of certain soils.

In South Carolina, Cooper, *et al* (3)[3] found that coarse-textured soils, such as Norfolk and Durham, were seriously affected. Applications of only 50 pounds of calcium arsenate per acre greatly reduced the yield of cotton on Durham coarse sandy loam. The fine-textured dark-colored soils, such as Greenville, Cecil, and Davidson, were not seriously affected by arsenate applications commonly used to combat boll weevil. In Louisiana, Reed and Sturgis (8) found no detrimental effect upon cotton production but obtained a toxic effect upon rice following cotton dusted with calcium arsenate. The toxicity was greater in Crawley very fine sandy loam than in Crawley silty clay loam. Craft (4), investigating the use of trivalent arsenic for soil sterilization, found soil toxicity greatest in Fresno, a sandy loam, and least in Yolo, a clay loam.

As commonly practiced in the cotton-growing area, there is no regularity in the application of calcium arsenate, either in quantity applied or frequency of applications. The quantity applied per acre at each application may vary from 3 to 10 pounds, depending upon the size of the cotton, and the number of applications in a given season may vary from one to six.

However, the quantity of calcium arsenate which finds its way into the soil is not as great as might be expected. It probably will not exceed 30 pounds per acre annually over a period of years, even on well-managed farms in areas of intense cotton production.

The increasing use of arsenical compounds for insect control, the possibility of conditions necessitating larger applications, and the likelihood of an accumulative effect from calcium arsenate seem to require more exact knowledge. It is the purpose of this paper to show the effect of calcium arsenate treatments upon the cotton yields from several important soil types.

EXPERIMENTAL

SOILS

Used in this study were three upland soils, Memphis silt loam at Holly Springs, Mississippi, Houston clay loam at West Point, Mississippi, and Ruston sandy

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[3]Figures in parenthesis refer to "Literature Cited", p. 970.

loam at Poplarville, Mississippi, and two delta soils, Sarpy silty clay loam at Tallulah, Louisiana, and Sarpy fine sandy loam at Stoneville, Mississippi.

Memphis silt loam is a well-drained productive soil developed from loess. The areas lie adjacent to but above the bottomlands on both sides of the Mississippi River southward from the vicinity of St. Louis almost to the Gulf of Mexico.

Houston clay loam is a well-drained soil of the Blackland Prairies occurring chiefly in Texas, Mississippi, and Alabama. The surface soil is black or nearly black clay loam; the subsoil is generally grayish-yellow or yellow clay; the substratum consists of marl or chalk.

Ruston sandy loam is a well-drained soil of the Atlantic and Gulf Coastal Plain. The surface soil is grayish-brown sandy loam; the subsoil is reddish-brown friable sandy clay, with substratum of unconsolidated Coastal Plain materials. It is one of the most widely distributed soils of the Coastal Plain Region. The materials are generally medium or strongly acid throughout.

The soils called Sarpy silty clay loam and Sarpy fine sandy loam occur in the first bottoms of the Mississippi River. They are generally fertile soils composed of recent alluvium and are among the best cotton soils in the Mississippi Delta Region.

TREATMENTS

Field plats, 1/40 acre in size with three replications, were treated with the following amounts of calcium arsenate in 1935: 0, 50, 100, 200, 400, 800 and, 1,600 pounds per acre. All soil types received the same treatment except Sarpy silty clay loam. The test on this soil contained only two plats, 1/7 acre in size, one plat receiving 400 pounds of calcium arsenate in 1934 and every year thereafter for 5 years, making a total of 2,000 pounds, the other receiving no arsenate.

Calcium arsenate was broadcast on the treated plats and disced into the soil to a depth of 4 or 5 inches. Applications were made in the spring before cotton was planted.

Four hundred pounds of 4–8–4 were applied to all plats every year at planting time.

RESULTS AND DISCUSSION

The data in Tables 1 and 2 show the effect of calcium arsenate treatments upon the yield of cotton on the five soil types studies. It was planned to obtain at least four years' results on all soil types, but

TABLE 1.—*Average yield of cotton on several soil types treated with calcium arsenate.*

Pounds of calcium arsenate per acre	Houston clay loam, 3-year average	Memphis silt loam, 1-year average	Sarpy fine sandy loam, 1-year average	Sarpy silty clay loam, 5-year average
0	991	788	1,724	1,794
50	1,065	819	1,608	—
100	1,030	850	1,656	—
200	982	831	1,568	—
400	1,025	794	1,809	—
800	1,013	799	1,838	—
1,600	1,036	783	1,692	—
2,000 (400 lbs. every year)	—	—	—	1,178

cotton was only grown one year on Memphis silt loam and Sarpy fine sandy loam and three years on Houston clay loam. All results obtained are presented in Tables 1 and 2.

TABLE 2.—*Yield of cotton on Ruston sandy loam treated with calcium arsenate in 1935.*

Pounds of calcium arsenate per acre	Yield of seed cotton in pounds per acre				
	1935	1936	1937	1938	4-year average
0	708	1,145	1,314	1,120	1,072
50	882	1,275	1,490	1,164	1,203
100	868	1,446	1,630	1,340	1,321
200	570	1,262	1,608	1,170	1,152
400	490	912	822	1,220	861
800	584	758	655	932	732
1,600	240	0	206	566	253

On the Houston clay loam no harmful effect was obtained, either in plant growth or yield of cotton, even when as much as 1,600 pounds of calcium arsenate were applied to the soil. The yield was 1,036 pounds per acre which is slightly more than the yield of 991 pounds given by the untreated plats. Most arsenate-treated plats outyielded the untreated plats, but it is doubtful if these increases are significant.

The results on Memphis silt loam are very similar to those obtained on Houston clay loam. All plats treated with calcium arsenate yielded just as much as the one receiving no calcium arsenate.

Five years' results on Sarpy silty clay loam show that a treatment of 400 pounds of calcium arsenate every year did not affect the yield of cotton. The plat which received 2,000 pounds of calcium arsenate over a period of five years yielded 1,778 pounds and the untreated plat 1,794 pounds of seed cotton per acre. Oats planted on both plats after five years treatment showed no injury from the calcium arsenate. The calcium arsenate treatments used on this soil were much greater than the average yearly treatment which did not exceed 30 pounds per acre in the Mississippi Delta.

Although the cotton yields from the Sarpy fine sandy loam were inconsistent, they indicate that no injurious effect was obtained from the heavy calcium arsenate treatments which gave as much seed cotton per acre as the untreated plat.

The cotton results on Ruston sandy loam (Table 2) show a definite increased yield every year from the lighter applications. In 1935, immediately after the arsenate was applied, only the 50- and 100-pound plats gave an increase over the untreated plat, and applications heavier than the 100 pounds reduced the cotton yield. In 1936, however, the 200-pound plot, as well as the 50- and 100-pound plats, gave a marked increase over the untreated plat. In 1938, four years after the arsenate was applied, the 400-pound treatment also gave a significant increase over the untreated plat and even the 800- and 1,600-pound treatments had lost much of their toxicity.

These data show that the toxicity of calcium arsenate was reduced with time. Only four years were required for the toxic influence of 400 pounds of calcium arsentate to be lost. It is doubtful if as much as 200 pounds of calcium arsenate is ever applied within four years, and these results indicate that even this quantity would not cause a decrease in cotton yields. The four years' average show that the 50-, 100-, and 200-pound treatments yielded 131, 245, and 80 pounds per acre, respectively, more than no treatment. The heavier applications greatly decreased the cotton yields. The plats treated with 1,600 pounds of calcium arsenate averaged only 253 pounds, a decrease of 819 pounds of seed cotton per acre due to the arsenate.

The results suggest that no effect, either beneficial or deterimental, may be expected from calcium arsenate applications to cotton grown on Houston clay loam, Memphis silt loam, Sarpy silty clay loam, or Sarpy fine sandy loam. However, on Ruston sandy loam there is a beneficial effect upon the yield of cotton from light applications and a detrimental effect from heavy applications of calcium arsenate.

In order to investigate the cause of variations in cotton response on different soils, the pH value and the percentage of CaO, Fe_2O_3, and P_2O_5 were determined in each soil. The percentage of clay was also determined by the Boyoucos method (1). These data are shown in Table 3. Ruston sandy loam, the soil which was affected by the heavy arsenate treatments, was much more acid than the other soils. This agrees with results obtained by Cooper, *et al* (2) who found that high acidity seems to increase the toxic effect of heavy applications of calcium arsenate. Of course, the total CaO and Fe_2O_3 content is not indicative of the activity of these elements in fixing arsenic, but it is interesting to note that the percentage of CaO and Fe_2O_3 was much higher in the more tolerant soils, which agrees with the report of Greaves (5) that calcium may render arsenic somewhat insoluble, and with the findings of Cooper, *et al* (2) that lime and iron helped counteract the harmful effect of arsenic.

TABLE 3.—*Important constituents of the soils.**

Soil type	pH	CaO, %	Fe_2O_3, %	Clay, %
Houston clay loam	6.2	1.53	4.22	48.0
Memphis silt loam	5.9	0.35	2.62	27.2
Ruston sandy loam	5.0	0.20	1.35	8.4
Sarpy fine sandy loam	6.2	1.00	2.62	25.8
Sarpy silty clay loam	6.3	1.24	3.85	24.0

*pH determined by potentiometer method; CaO and Fe_2O_3 determined by A. O. A. C. method.

The quantity of clay present suggests further reason for arsenic fixation. Houston clay loam, an unaffected soil, contained 48% colloidal material, whereas Ruston sandy loam, the soil most injured by calcium arsenate, contained only 8.4%, which indicates that the colloidal material is largely responsible for arsenic fixation. High pH and high colloidal content, which carries a high percentage of Fe_2O_3, seem necessary to make a large quantity of arsenic sufficiently insoluble to render it non-toxic to crops.

The beneficial effect of applications of 50 and 100 pounds of calcium arsenate on Ruston sandy loam was surprising. Other determinations have shown that this soil contains only 6 p.p.m. of available phosphorus by the Truog method (9) as well as low total P_2O_5 content. Unpublished results have shown that cotton tests conducted on adjoining plats have given a good response to both phosphorus and lime. Therefore, it is believed that the stimulated yield is due to three causes: First, the calcium applied as calcium arsenate counteracts the acidity and acts as a nutrient. Second, the arsenic either liberates or partially substitutes for the unavailable phosphorus in the soil. Third, the light application of calcium arsenate stimulates the bacterial activities of the soil. These deductions agree with Greaves' reports (6, 7) that arsenic can in some manner liberate phosphorus from its insoluble compounds, and that arsenic stimulates bacterial action, thereby increasing crop yields.

SUMMARY

The effect of different calcium arsenate treatments upon five important soils was determined by measuring the yields of cotton from these soils. The yields on four of the soils, Houston clay loam, Memphis silt loam, Sarpy silty clay loam, and Sarpy fine sandy loam, were unaffected even from an application of 1,600 pounds of calcium arsenate per acre. However, the yield of cotton on Ruston sandy loam was greatly affected. A beneficial effect was obtained from the light applications and a detrimental effect from the heavy applications of calcium arsenate. However, the arsenic toxicity was reduced with time. The beneficial effect was attributed to three causes, namely, the applied calcium acting as a nutrient, the arsenic liberating insoluble phosphorus, and the calcium arsenate stimulating bacterial action.

The ability of the unaffected soils to render arsenic insoluble was probably due to their high pH and high colloidal content.

The soils used in this study are representative of many in the cotton belt, and the results obtained from them indicate that on these soils there is very little danger of reducing cotton yields with calcium arsenate. Since the average yearly application to cotton is hardly ever more than 30 pounds per acre and since much of it is lost every year, accumulation in the soils studied will probably never be great enough to inhibit cotton production.

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SOME EFFECTS OF CONTOUR LISTING ON NATIVE GRASS PASTURES[1]

B. C. Langley and C. E. Fisher[2]

RECENT trends in range improvement have been toward increasing the cover of palatable forage plants through the utilization of a larger portion of the rainfall. Within large areas of the semiarid west it appears desirable to retain all of the rainfall, since range plants, especially the grasses, have the ability to use large amounts of water in the production of forage.

Most of the soils of the region are relatively deep and porous and provide ample storage space within the root zone for a large portion of the rainfall. On grassland with sparse vegetative cover, however, it is often expedient to use some kind of obstruction to check the movement of water, since the length of time that water is held on the land, as well as the infiltration rate of the soil type, determines to a large extent the amount that penetrates into the soil. Thus, the chief aim of mechanical structures is to retard the flow and give equal distribution of water over an entire area.

Studies were initiated at the Spur Substation in 1932 to obtain information on the effectiveness of contour listing of grassland in increasing vegetative cover and yield of forage. The increased production of grass resulting from this treatment was so striking that additional areas were listed in 1934 and in later years. The data on yields, basal cover, and moisture penetration from these studies are reported in this paper.

EXPERIMENTAL AREA

The native vegetation on the experimental area is characteristic of the shortgrass (Buchloe-Bouteloua) pastures of the region. Before listing treatments were begun, it consisted largely of open mat type of buffalo grass (*Buchloe dactyloides*), with small amounts of blue grama (*Bouteloua gracilis*), purple three awn (*Aristida purpurea* and *A. Roemeriana*), and traces of many other grass species. Some of the more important weeds occurring on the area were broomweed (*Gutierrezia dracunculoides*), Indian wheat (*Plantago Purshii* and *P. spinulosa*), bitterweed (*Actinea odorata*), and peppergrass (*Lepidium densiflorum*). Small amounts of cacti and Yucca species were also present. The area supported in addition a rather heavy growth of mesquite brush (*Prosopis chilensis*) and a few plants of lote bush (*Condalia obtusifolia*). These shrubs were removed by grubbing as they were competing with desirable pasture plants.

The soil on which these studies were made is Miles clay loam, with a slope of 1–3%. Some sheet erosion has occurred on the steeper slopes and small gravel are present at the surface; however, there is no evidence of gully formation. Locally

[1]Contribution from the Texas Agricultural Experiment Station, Spur, Texas, in cooperation with the Soil Conservation Service, U. S. Dept. of Agriculture. Received for publication September 15, 1939.

[2]Agronomist and Assistant Soil Conservationist, respectively. The writers gratefully acknowledge the suggestions and assistance of Mr. R. E. Dickson, Superintendent of Texas Substation No. 7, in outlining and conducting the work and in preparing the manuscript.

this soil is referred to as "tight" or "droughty" and is not well adapted to the production of cultivated crops.

PROCEDURE

Plats of approximately 1 acre were solid listed on contours to a depth of 3 inches during the spring of 1932, 1934, 1936, and 1938. Comparable adjoining plats were given no treatment. A two-row tractor lister with bottoms set 39 inches apart was used in the listing operation.

In order to protect representative samples of the vegetation from grazing animals, five screens, the framework of which were constructed of 2-inch by 4-inch lumber and covered with 2-inch wire netting, were located on each plat. The screens covered an area of 4 feet by 6 feet and were placed 12 inches above the ground level.

Harvests for yield comparisons on the areas thus protected were made when the grass reached maturity or when plants became dormant because of drought. Two or three harvests were made yearly, the number depending largely on vegetative growth as influenced by the amount and distribution of rainfall. The vegetation was clipped to simulate close grazing, and green and air-dry weights of grass and weeds obtained. New sites for obtaining yield data on the plats were selected each year to avoid cumulative effects of protection from grazing.

Soil moisture samples were taken monthly during the growing season at each protecting screen to determine the effect of listing on the amount of available moisture and depth of penetration. Samples were taken at 1-foot levels to a depth of 6 feet with a 1-inch diameter soil tube, and dried to constant weight in an oven at 110° C.

Measurements of basal cover were made on meter quadrats on each plat during the growing season. The pantograph-chart method was used since it is well adapted for use in a study of the short grasses and open sod type of the other grasses (4).[3] The percentage of basal cover and percentage of total cover occupied by each species were determined from the charts by means of a planimeter.

In making determinations of root volume and weight, a column of soil 15 inches square and 66 inches deep was removed in 6-inch layers, and the roots carefully removed from the blocks by washing the mass over a fine screen with a spray of water, after the method described by Weaver and Harmon (5). The determinations of volume were made while the roots were water soaked, but excess water was removed from the root surfaces with blotters.

EXPERIMENTAL RESULTS

YIELD OF NATIVE VEGETATION

The rapidity with which grass becomes re-established after listing depends largely upon the abundance of those species which have the ability to reproduce vegetatively. Buffalo grass, under only moderately favorable conditions, rapidly increases vegetatively by means of stolons. The upper part of Fig. 1 shows a plat of buffalo grass just after it was listed in 1936. The berm left on each side of the furrows provides sufficient grass to vegetate completely the furrows and ridges in a favorable season. The lower part of Fig. 1 shows the same plat in 1937 at the end of the second growing season after listing.

[3]Figures in parenthesis refer to "Literature Cited", p. 981.

Yields from listed and unlisted plats are presented in Table 1. No yields are reported from the 1932 listing for the reason that differences in soil type preclude a comparison of the 1932 yields with those obtained from treatments made in other years. During the period of 1935 to 1938 an average yield of 630 pounds of air-dry grass per acre

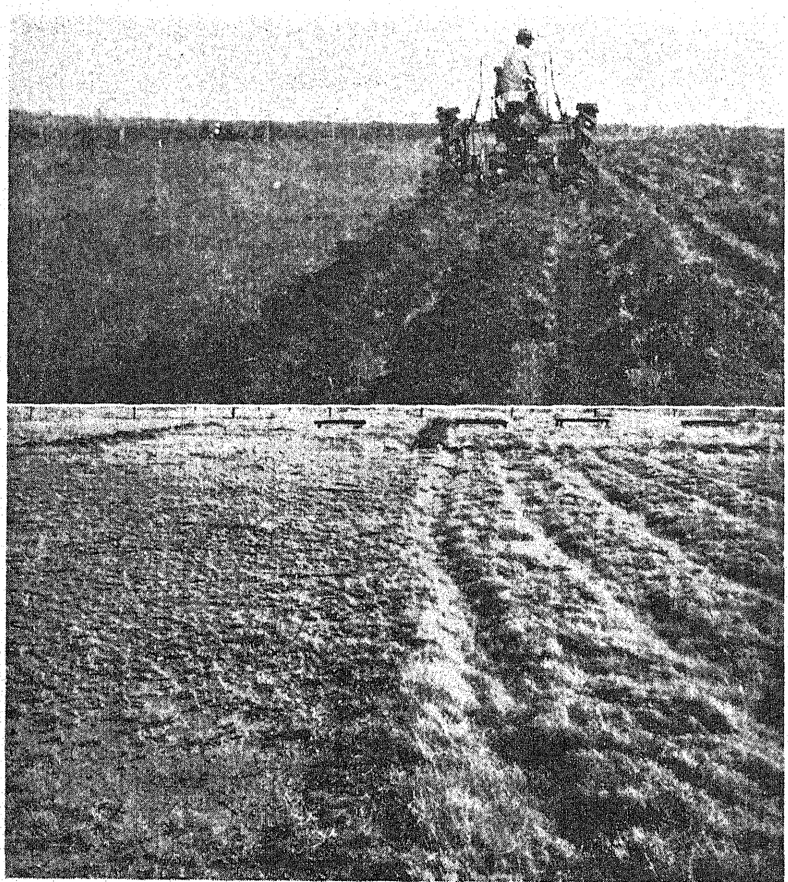

FIG. 1.—*Upper*, plat of native pasture following listing in 1936. *Lower*, same plat at the end of the growing season in 1937.

was made by the unlisted areas as compared with 1,812 pounds from the area listed in 1934. Comparable averages for shorter periods, including results from listing treatments made in later years, show that grass production was increased 2.3 to 3.9 times by listing. The highest annual yield from any one treatment, 2,424 pounds of grass per acre, was obtained in 1935 from the 1934 listing.

Yields from the plats the first year following spring listing have been consistently greater than from those not listed. The amount of

grass cover destroyed during the early part of the season, as evidenced in Fig. 1, was compensated for by increased vigor, greater height, and prolonged growing season of the vegetation. In the early years of the study the increase from listing was attributed largely to the conserving of the rainfall (3), but numerous field observations made through the years indicate that some of the increase may have been caused by the cultivation or loosening of the soil. Studies which have as their objective the isolation of some of the factors involved in this phase of the problem are now under way.

In 1935 and 1936 weeds occurred only in trace amounts and no distinction was made between grass and weeds in reporting yields for these years. Increased weed growth in 1937 and 1938, however, justified weighing and reporting grass and weeds separately. Data in Table 1 show that growth of weeds, mostly annuals, may increase the first year after listing, but these usually disappear as the furrows and ridges become vegetated with grasses. After a period of years weeds have practically disappeared on listed areas.

TABLE 1.—*Acre yields in pounds of air-dry grass and weeds from contour listed and unlisted grassland, 1935–1938.*

Treatment	1935, grass	1936, grass	1937, Grass	1937, Weeds
Unlisted	858	592	259	30
Listed 1934	2,424	2,315	1,133	76
Listed 1936	—	1,326	2,159	185
Listed 1938	—	—	—	—

Treatment	1938, Grass	1938, Weeds	1935–38, av. grass	1936–38, av. grass	1937–38, Grass	1937–38, Weeds
Unlisted	810	403	630	554	534	216
Listed 1934	1,376	107	1,812	1,608	1,254	92
Listed 1936	1,973	231	—	1,819	2,066	208
Listed 1938	1,178	491	—	—	—	—

SOIL MOISTURE CONTENT

In order to minimize the effect of any existing variation in soil type, the moisture data are expressed in inches of available water rather than as a percentage relationship of total water to dry soil. Accordingly, moisture samples were taken during the growing season when it was evident that the water available to plants had been consumed and the vegetation was dormant. The average moisture under these conditions is the amount not available to plants. This degree of moisture depletion has been termed the "minimum point of exhaustion" (2). The so-called available water is obtained by deducting the minimum point of exhaustion from the total moisture.

The value of listing as a water conserving practice is revealed in the increase of available moisture and depth of penetration (Table 2).

The average available moisture in 1937 and 1938 to a depth of 6 feet was 1.32 inch on the unlisted areas. Of this amount, 76.52% was present in the upper 2 feet, while only 23.48% was stored in the lower 4 feet. On grassland that was listed in 1934, 3.12 inches of available water was stored in the soil. The upper 2 feet contained 50.64% of the moisture and the lower 4 feet contained 49.36%. A similar increase in the supply of available moisture and in penetration was obtained on land listed in 1936.

TABLE 2.—*Annual and average quantities of available water in the surface 6 feet of the soil during the growing season and percentage distribution at different depths, 1937–38.*

Depth of sampling, feet	Average amount of available water in the soil during the growing season, inches			Percentage of average available moisture		
	1937	1938	Average	Each foot	Upper 2 feet	Lower 4 feet
			Unlisted			
1	0.86	0.59	0.72	54.55	76.52	23.48
2	0.39	0.19	0.29	21.97	—	—
3	0.04	0.08	0.06	4.54	—	—
4	0.00	0.03	0.02	1.52	—	—
5	0.12	0.19	0.16	12.12	—	—
6	0.00	0.14	0.07	5.30	—	—
Total	1.41	1.22	1.32			
			Listed, 1934			
1	1.17	0.77	0.97	31.09	50.64	49.36
2	0.78	0.44	0.61	19.55	—	—
3	0.62	0.42	0.52	16.67	—	—
4	0.53	0.26	0.40	12.82	—	—
5	0.56	0.16	0.36	11.54	—	—
6	0.41	0.11	0.26	8.33	—	—
Total	4.07	2.16	3.12			
			Listed, 1936			
1	1.17	0.69	0.93	27.27	46.63	53.37
2	0.81	0.50	0.66	19.35	—	—
3	0.78	0.54	0.66	19.35	—	—
4	0.68	0.37	0.52	15.25	—	—
5	0.39	0.17	0.28	8.21	—	—
6	0.56	0.15	0.36	10.56	—	—
Total	4.39	2.42	3.41			
			Listed, 1938			
1	—	0.75	—	32.19	61.37	38.63
2	—	0.63	—	29.18	—	—
3	—	0.37	—	15.88	—	—
4	—	0.32	—	13.73	—	—
5	—	0.21	—	9.01	—	—
6	—	0.00	—	0.00	—	—
Total		2.33				

On numerous occasions following heavy rain periods noticeably increased moisture penetration occurred on the listed pasture areas. Determinations made before and soon after a heavy rain period in 1936 showed that the average moisture penetration was to a depth of 72 inches on the listed plats as compared to 30 inches on the unlisted, and the amount of available moisture stored was 6.67 and 2.10 inches, respectively.

Measurements made at the end of the 1938 growing season show that the following amounts of rain falling on each listed area would be retained in the furrows without allowing for any penetration: 1932 listing, 0.80 inch; 1934 listing, 0.84 inch; 1936 listing, 0.95 inch; 1938 listing, 1.03 inch. Although the furrows form only a small reservoir, the combined effect of a high infiltration rate and the furrows' serving as a catchment basin is to increase materially the opportunity for the penetration of large amounts of water. It is evident that with the passing of time the retentive capacity of the furrows is somewhat reduced by slowly filling in with soil.

BASAL COVER AND COMPOSITION OF COVER

A distinct change occurred in the basal cover and composition of native vegetation following listings made in 1932 and 1934. To obtain definite information regarding those changes, 5-meter quadrats were located at representative points on each plat and charted in 1937 and 1938. The basal cover represents that portion of the soil surface covered by living plants. Where plant parts were less than 1 cm distant, the area was considered as being fully covered.

The most outstanding change in cover was the increase in buffalo grass following listing treatments. The average basal cover of this grass in 1937 and 1938 was 14.02% on unlisted grassland and 64.96% on grassland listed in 1934 (Table 3). Similar increases in cover of buffalo grass were obtained from the treatments made in 1936 and 1938. It is also of interest that only 44.96% of the total cover of the vegetation on the unlisted grassland was buffalo grass, as compared to 87.04% on the area listed in 1934, 82.07% on the area listed in 1936, and 85.23% on that listed in 1938.

Listing has brought about only minor changes in the basal cover of the other grasses. Little barley (*Hordeum pusillum*) appears to increase the first year following listing but is gradually replaced by perennial grasses. The cover of purple three awn, which has a low palatability to most classes of livestock, seems to decrease gradually over a period of years after listing. Grassland that was listed in 1932 and 1934 shows a reduction in cover of purple three awn, while the cover of this species on grassland listed in 1936 has remained practically the same. In all cases, however, the percentage of cover provided by purple three awn in comparison to the total vegetative cover has been reduced by listing.

The basal cover of all weed species, especially that of Indian wheat, peppergrass, and bitterweed, has been appreciably reduced by listing. The marked reduction of bitterweed is of particular importance to stockmen, since this plant is poisonous to sheep. Dameron and Cory

TABLE 3.—*Average percentage, 1937 and 1938, of basal cover and total cover of native vegetation on contour listed and unlisted grassland.*

Species	Common name	Unlisted		Listed, 1934		Listed, 1936		Listed, 1938*	
		Basal cover	Total cover	Basal cover	Total cover	Basal cover	Total cover	Basal cover	Total cover
Grasses:		21.46	68.83	70.28	94.17	75.60	93.16	48.30	91.60
Buchloe dactyloides	Buffalo grass	14.02	44.96	64.96	87.04	66.60	82.07	44.94	85.23
Bouteloua gracilis	Blue grama	0.78	2.50	2.18	2.92	1.41	1.74	0.60	1.14
Aristida purpurea and *A. Roemeriana*	Purple three awn	4.23	13.57	1.62	2.17	4.74	5.84	1.84	3.49
Hordeum pusillum	Little barley	0.80	2.57	0.56	0.75	2.24	2.76	—	—
Schedonnardus paniculatus	Tumblegrass	0.96	3.08	0.52	0.70	0.20	0.25	0.60	1.14
Others		0.67	2.15	0.44	0.59	0.41	0.51	0.32	0.61
Weeds:		5.41	17.35	2.60	3.48	3.13	3.86	4.43	8.40
Plantago spinulosa and *P. Purshii*	Indian wheat	3.46	11.10	1.62	2.17	1.34	1.65	—	—
Ledpidium densiflorum	Pepper grass	1.16	3.72	0.08	0.11	0.38	0.47	—	—
Verbena bipinnatitida	Wild verbena	Trace	Trace	0.04	0.05	Trace	Trace	—	—
Others		0.79	2.53	0.86	1.15	1.41	1.74	4.43	8.40
Undesirable weeds:		4.31	13.82	1.75	2.34	2.42	2.98	—	—
Actinea odorata	Bitterweed	3.82	12.25	0.17	0.23	0.47	0.58	—	—
Senecio longilobus	Threadleaf grounsel	0.15	0.48	0.94	1.26	0.41	0.51	—	—
Others		0.34	1.09	0.64	0.86	1.54	1.90	—	—
Total basal cover, %		31.18	—	74.63	—	81.15	—	52.73	—
Unprotected soil, %		68.82	—	25.37	—	18.85	—	47.27	—

*Two quadrats.

(1) also have found that the cover of bitterweed is reduced as the cover of turf grasses increases.

UNDERGROUND PLANT MATERIALS

Determinations of root volume and weight were made at two locations selected at random on an unlisted area and on the area listed in 1934. Roots are reported by weight on oven-dry basis and by volume in cubic centimeters of water displaced (Table 4). The root system was 63.63% greater in volume and 78.91% greater in dry weight from the listed than from the unlisted plat. Likewise, the maximum penetration of roots was to a depth of 66 inches and 44 inches on the two plats, respectively.

TABLE 4.—*Volume and weight of underground plant materials from contour listed and unlisted grassland, 1936.*

Depth, inches	Water displaced, cc		Oven-dry material, grams	
	Listed*	Unlisted	Listed*	Unlisted
1–6	464	259	95.14	45.14
8–14	60	56	11.33	10.49
16–22	27	25	7.19	7.03
24–30	15	13	3.87	3.78
34–40	12	10	1.96	1.34
42–48	9	Trace	1.38	0.11
50–56	6	0	0.52	0.0
60–66	1	0	0.07	0.0
Total	594	363	121.46	67.89
Increase, %	63.63		78.91	

*In 1934.

A visual representation of the amount of roots found at different depths is shown in Fig. 2. The slightly darker shade of color of the roots from the unlisted plat is the result of the large number of dead roots found in the mass. Since roots exist in the soil in all stages of decomposition, it is not to be expected that all of the underground materials are living; however, at every depth the unlisted land has a much higher proportion of dead materials than that which was listed. The roots from the listed plat were relatively free from dead materials and for the most part appeared to be in a vigorous growing condition.

TABLE 5.—*Amount and ratio of oven-dry plant materials from contour listed and unlisted grassland, 1936.*

Treatment	Oven-dry materials per acre, tops			Ratio of tops to roots
	Dry grass	Roots*	Total	
Listed in 1934	1.066	3.732	4.798	1:3.50
Unlisted	0.327	2.086	2.413	1:6.38

*Depth, 66 inches.

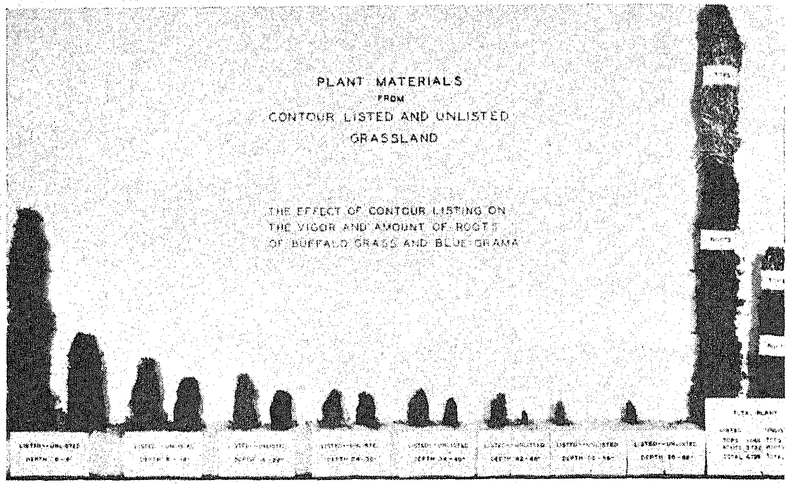

FIG. 2.—From left to right in pairs, roots of buffalo and blue grama grass that were removed at intervals of 6 inches to a depth of 66 inches from listed and unlisted areas. At extreme right, total roots and tops from listed and unlisted areas, roots removed to depth of 66 inches.

The amount of plant materials and the ratio of roots to tops are shown in Table 5. The weight of roots from either of the treatments far exceed the weight of forage. The ratio of tops to roots on listed and unlisted plats is 1:3.50 and 1:6.38, respectively. In the case of the unlisted plat the ratio of tops to roots is wide, probably because of the larger proportion of dead roots present.

SUMMARY

Grassland with a cover consisting primarily of buffalo grass was solid listed on contours to a depth of 3 inches with the following results:

1. Yields of grass were increased as much as 3.9 times, the highest annual yield from any one treatment being 2,424 pounds of air-dry grass per acre.

2. Increases in available soil moisture and depth of penetration were reflected in higher yields of grass, greater basal cover, and the tendency of the listed areas to remain green longer during periods of deficient rainfall.

3. The most important vegetal change was the large increase in cover of buffalo grass, which was accompanied by a marked decrease in cover of weeds and area of bare soil.

4. A greater volume and deeper penetration of roots occurred on listed grassland. A high percentage of roots on unlisted grassland appeared to be dead, while those from the listed area were in a vigorous growing condition.

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HARMFUL ROOT INTERACTIONS AS A POSSIBLE EXPLANATION FOR EFFECTS NOTED BETWEEN VARIOUS SPECIES OF GRASSES AND LEGUMES[1]

H. L. AHLGREN AND O. S. AAMODT[2]

MANY species of plants and more particularly those used for hay or pasture purposes are sown in mixtures. Dominance of any given species in any particular environment has usually been attributed to differential moisture, temperature, light, and fertility requirements. Investigations have shown that the development and activity of the roots of certain species of plants may be affected by the metabolism of adjoining roots and that some species of plants may have a specific effect on other species which follow in the rotation. An excellent review of the literature on this subject has been made by Loehwing.[3] There is considerable difference of opinion in the literature as to the cause of specific interactions which have been noted. Toxic secretions, deficient oxygen, excessive carbon dioxide and moisture, harmful pH, and nitrogen starvation are among the more important factors listed as being involved in specific root interactions.

It is the purpose of this preliminary report to call attention to the possible existence of harmful root interactions between various species of pasture grasses and legumes and the need for further investigations relative to the extent and importance of this phenomenon under varying light, moisture, temperature, and fertility conditions.

Extensive botanical studies relative to the effect of various fertilization and management treatments on the productivity and survival of a number of species of plants used for hay and pasture purposes were begun at the University of Wisconsin in 1935. Included among the species studied were Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*), redtop (*Agrostis alba*), red clover (*Trifolium pratense*), alsike clover (*Trifolium hybridum*), and white clover (*Trifolium repens*). Field observations made since the experiment was initiated seemed to indicate that a number of species interactions occurred which could not be accounted for on the basis of differential response to light, temperature, moisture, fertilization, and management. White clover and red clover were seldom found in dense, closely grazed quack grass (*Agropyron repens*) sod whereas alsike clover appeared in comparative abundance. Canada bluegrass (*Poa compressa*), although not seeded, was found in areas which were not fertilized with commercial nitrogen. Canada bluegrass, redtop, timothy, and Kentucky bluegrass were observed to occur as definite colonies rather than blending uniformly throughout the sward. Redtop was eliminated early by Kentucky bluegrass.

In August of 1938 a series of experimental pasture and meadow field plats were sown to compare the yield and survival of two strains of brome grass (*Bromus inermis*), both commercial and parkland,

[1]Published by permission of the Director of the Wisconsin Agricultural Experiment Station. Received for publication September 17, 1939.

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[3]LOEHWING, W. F. Root interactions of plants. Bot. Rev., 3:195–239. 1937.

timothy, and Kentucky bluegrass under various soil treatments and management programs. One of the variables consisted of a mixture of red, white, and alsike clovers sown across the grass plats which were replicated six times. All of the plats had perfect stands of grasses and legumes in the fall before growth was stopped by low temperatures. A mild winter followed, although there was little snow cover.

After growth of the plants started in the spring of 1939 it was soon evident that a very marked differential interaction had taken place between the clovers and *one* of the grasses. The stands of the two strains of brome grass and timothy were uniformly good on all the plats regardless of treatment or association with legumes. The Kentucky bluegrass, however, was practically eliminated from that portion of each plat on which the clovers were growing in association with the grass. The other three grasses were not in any way affected by the legumes. There appeared to be no other probable explanation of the striking apparent interaction between the clovers and the Kentucky bluegrass in this experiment.

In order to obtain more specific data on these apparent interactions, preliminary studies were begun under controlled conditions in the greenhouse in an attempt to determine if measurable effects could be obtained between various associations of Kentucky bluegrass, Canada bluegrass, redtop, and timothy.

Seedling plants of Kentucky bluegrass, redtop, timothy, and Canada bluegrass were transplanted to non-sterilized soil (¾ Carrington silt loam and ¼ sand) in greenhouse benches on October 25, 1938. Pure culture plats of Kentucky bluegrass, timothy, redtop, and Canada bluegrass were established. Three rows of 16 plants each with plants spaced 2 inches apart constituted a plat. Each plat was duplicated and separated by a 6-inch border from the adjacent plats. In addition to the pure cultures, combinations were used of (a) Kentucky bluegrass and redtop, (b) timothy and redtop, and (c) Canada bluegrass and Kentucky bluegrass. The plan of procedure in the case of the combinations was similar to that used in the pure cultures excepting that individual plants of each species being studied were alternated in each row. The temperature in the greenhouse was maintained at 60° to 65° F during the experiment

The root and top growth produced by the various species growing in pure culture and in combinations was determined from five random plants of each species selected from the center row of each duplicate plat. Plants at the end of the row were not used. After each harvest all of the remaining plants were cut back to soil level. Cuttings to determine the amount of foliage produced by plants growing on the various plats were made on January 30 and on March 14, 1939. The roots were removed from the soil on March 18, washed, and the weight on an oven-dry basis determined.

The data obtained in the study were analyzed according to Fisher's analysis of variance and are given in Tables 1 and 2. The calculated minimum difference at the 5% point for yield of foliage was found to be 0.44 gram. From a study of the data it is apparent that a number of significant species interactions occurred. The average weight of

dry matter in the foliage of each plant of Canada bluegrass was 0.26 gram when grown in combination with Kentucky bluegrass, and 0.45 gram when grown in pure culture. The average weight of foliage per plant of timothy was 0.36 gram when grown in combination with redtop and 0.58 gram when grown in pure culture. Likewise, the average weight of the foliage produced per plant of Kentucky bluegrass was 0.195 gram when grown with redtop and 0.343 gram in pure culture. The yield of redtop was lower when grown in combination with timothy and Kentucky bluegrass, but the reduction was not great enough to be statistically significant. The yield of Kentucky bluegrass was also lower, though not significantly so, when grown with Canada bluegrass.

TABLE 1.—*Average dry weight per plant of the foliage of Kentucky bluegrass, Canada bluegrass, redtop, and timothy grown in pure culture and in various coombinations.*

Species	Average weight per plant in grams*
Pure Cultures	
Redtop	0.369
Kentucky bluegrass	0.343
Canada bluegrass	0.450
Timothy	0.577
Timothy and Redtop	
Timothy	0.360
Redtop	0.294
Kentucky Bluegrass and Redtop	
Kentucky bluegrass	0.195
Redtop	0.311
Canada Bluegrass and Kentucky Bluegrass	
Canada bluegrass	0.260
Kentucky bluegrass	0.264

*Each figure recorded represents the average weight per plant of 20 individual plants. Minimum difference required for significance at the 5% point = 0.44 gram.

The average weight of roots produced per plant by each of the species studied is given in Table 2. The calculated difference required for significance at the 5% point in the case of root production was found to be 0.11 gram per plant. The average weight of dry matter in the harvested roots of each plant of timothy was 0.221 gram when grown in combination with redtop and 0.339 gram when grown in pure culture. The average weight of the roots of each plant of Canada bluegrass was 0.137 gram when grown in a combination which included Kentucky bluegrass and 0.287 gram when grown in pure culture. In all other cases the roots of the plants grown in combinations was reduced, although differences were not great enough to be statistically significant.

The data presented would appear to indicate that harmful root interactions may occur between various species of pasture grasses

TABLE 2.—*Average dry weight per plant of the roots of Kentucky bluegrass, Canada bluegrass, redtop, and timothy grown in pure culture and in various combinations.*

Species	Average weight of roots per plant in grams*
Pure Cultures	
Redtop	0.244
Kentucky bluegrass	0.199
Canada bluegrass	0.287
Timothy	0.339
Timothy and Redtop	
Timothy	0.221
Redtop	0.184
Kentucky Bluegrass and Redtop	
Kentucky bluegrass	0.151
Redtop	0.222
Canada Bluegrass and Kentucky Bluegrass	
Canada bluegrass	0.148
Kentucky bluegrass	0.137

*Each figure recorded represents the average weight per plant of the roots of 20 individual plants. Minimum difference required for significance at the 5% point = 0.110 gram.

and legumes. These interactions are no doubt profoundly influenced by environmental conditions. Their full significance will not be known until they have been tested under various light, fertility, and management conditions. There is need for intensive fundamental study relative to the nature of these interactions and their effect on grass and legume species now commonly used in pasture and meadow mixtures.

NOTE

A SOIL MOISTURE TENSIOMETER WITH A COMPACT MANOMETER[1]

RECENT experiments have shown that a vacuum gauge, when attached to a porous cell which is filled with water and buried in soil, provides a convenient indication of the condition of the moisture in the soil. Such a device, of course, will operate successfully only over a soil moisture tension range somewhat less than 1 atmosphere. For greenhouse pot experiments, however, there is indication that the moisture condition for optimum growth lies well within this range.

The compact form of manometer shown in Fig. 1 has been used on tensiometers installed in greenhouse pots to aid in determining when water is needed, and the amount to be applied. Making the manometer is a relatively simple glass blowing operation. The range and accuracy desired in the measurements will determine the dimensions of the various parts. The relation of the manometer reading x, in cm, to the tension in the cup water t, in cm of mercury, is indicated by the formulae

$$(v_1+la+v_2)\left(Po-\frac{12.5}{13.5}h_2+h_3\right)=nRT \tag{1}$$

$$(v_1+xa)\,(B-t+x)\left(1+\frac{12.5}{13.5}\frac{a}{A}\right)+h_1-\frac{12.5}{13.5}\left(+h_2+\frac{h_4}{12.5}+\frac{v_2}{A}+\frac{la}{A}\right)=nRT \tag{2}$$

These equations are simply the gas law expressions for the volume and pressure of the air in the closed arm as related to the barometric pressure B and the absolute temperature T. The symbols h_1, h_2, h_3, and h_4 represent the distances from these several points to the top of the air trap. The cross sectional areas of the closed and open arms of the manometer are, respectively, a and A and l is the length of the capillary section.

During operation the air in the closed arm has a pressure less than that of the atmosphere. To accomplish this, the side arm c is filled with dry mercury and then, after filling the porous cell with water, a vacuum pressure Po is applied at the air trap. During this air removal process the mercury stands at the dotted levels h_2 and h_3, and v_1 and v_2 are, respectively, the volumes of the closed arm above and below the capillary. In general it is desirable that Po be of the order of a tenth of an atmosphere or less so that high tensions will not change the zero setting. The constants nR in equation (2) may be eliminated by use of equation (1).

A linear scale may be attached to the closed arm. Alternatively it has been found convenient to place several colored lacquer marks on the capillary tubes, corresponding to several known tensions. This calibration should be made from an open tube manometer attached to the air trap at the time of the zero setting. The effect of a change

[1]Journal paper No. J-673 of the Iowa Agricultural Experiment Station, Ames, Iowa. Projects 308 and 504.

in the atmospheric pressure or temperature on the tension indicated by the closed tube manometer may be calculated from equation (2). The manometers used in the pot experiments here reported were like the one shown in the scale drawing; for the use here described atmospheric pressure and temperature effects on the manometer reading may be neglected. The porous cups used were made by the General Ceramics Company, Refractories Division, 30 Rockefeller Plaza, New York, N. Y., cup No. K948.[2]

Thirty-eight hundred grams of soil were weighed into each of nine 1-gallon stoneware pots. Tensiometers were placed in each pot, midway between the side and center and at a depth which left 1 inch of soil below the bottom of the porous cell. Corn was planted and later thinned to four plants per pot. After the plants had reached a height of about 4 inches, three moisture levels—dry, intermediate, and wet—were established, each level being replicated three times. In the dry series water was withheld until the plants began to wilt, after which the tension was reduced to 50 cm of Hg by surface applications of water. In the intermediate series the tension was held between 30 and 50 cm and in the wet series between 0 and 30 cm.

After 52 days the plants were harvested and weighed. Table 1 gives the green weight, percentage moisture, and dry weight of the plants from each pot. The moisture content increased slightly with increased water supply as would be expected. The variation in plant growth within and between the treatments, measured by weight, may be taken as an indication of the accuracy of moisture control.

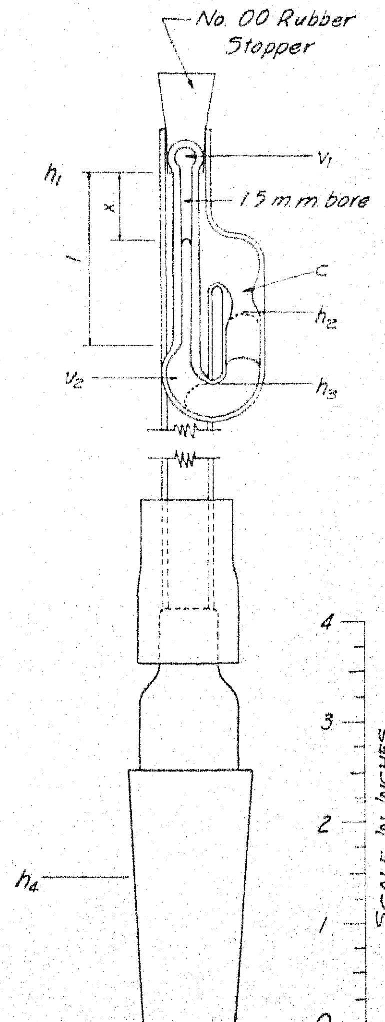

FIG. 1.—Type of manometer used.

[2]RICHARDS, L. A., RUSSELL, M. B., and NEAL, O. R. Further developments on apparatus for field moisture studies. Soil Sci. Soc. Amer. Proc., 2:55. 1937.

TABLE 1.—*Weight and percentage moisture of plant tissue produced at three levels of water supply.*

Pot No.	Wet series			Intermediate series			Dry series		
	Wet weight, grams	% moisture	Dry weight, grams	Wet weight, grams	% moisture	Dry weight, grams	Wet weight, grams	% moisture	Dry weight, grams
1	43.27	86.5	5.83	25.11	85.1	3.74	17.98	83.0	3.05
2	33.20	85.8	4.70	24.25	85.2	3.59	13.91	85.2	2.06
3	37.91	85.4	5.52	25.98	84.6	3.99	23.17	83.6	3.80
Average	38.12	86.6	5.35	25.11	85.0	3.44	18.35	83.9	2.97

The larger variation between checks in the dry series shows that at this low level the moisture was not regulated as closely as in the intermediate or wet series. In the intermediate series the moisture level was controlled more closely, as shown by the smaller variation between replications. Since intermediate moisture levels are desirable in most greenhouse work, the use of tensiometers for indicating time of irrigation and amounts of water to apply should prove satisfactory.

The distribution of moisture in the soils after harvest is given in Table 2. The pots had not been watered for 24 hours before samples were taken for moisture determinations. Composite samples from each series were used. The roots in the wet series were concentrated in the lower part of the soil, accounting for the lower moisture content in this region. In the intermediate series the roots were rather well distributed through the soil, with some tendency toward concentration in the lower part. In the dry series the roots were well distributed with some concentration both near the surface and in the lower part of the soil.

TABLE 2.—*Distribution of moisture in soils and average moisture content at time of harvest.*

Portion of soil	Wet series	Intermediate series	Dry series
Top ⅓	32.10	18.12	14.95
Center ⅓	33.05	19.20	15.88
Lower ⅓	24.08	17.61	16.36
Average	29.74	18.31	15.73

The moisture equivalent of the soil was found to be 28.7, which would indicate a wilting coefficient of about 15.6. The moisture content of the soils as determined should be the lower limit for each treatment, since the tensiometers indicated need for irrigation at the time of sampling. Thus, the lower limit for the dry series was very near the wilting point; in the intermediate series it was about 2.6% higher, and in the wet series it was very slightly above the moisture equivalent.

To change the reading of a tensiometer requires a transfer of water between cup and soil. Because of the low rate of moisture movement

in relatively dry soils (tensions above 50 cm of mercury), tensiometers will not reliably indicate soil moisture tension at any appreciable distance from the cup. This is especially true in the case of large tension gradients, as when plant root systems are in the neighborhood of the cup. It is rather unlikely after starting the moisture control in the dry series that soil moisture was ever uniformly distributed. The concentration of roots near the surface indicates that probably most of the moisture absorption took place in this region. With daily examination, the dry series was irrigated whenever wilting was observed, but the important thing to note is that only sufficient moisture was added to drop the tension of the soil moisture in the neighborhood of the porous cup to a minimum of 50 cm of mercury. It was occasionally necessary to refill the tensiometers in the dry series with water so as to remove accumulations of 2 or 3 cc of air, but no particular concentration of roots around the porous cups was observed in any of the pots.—L. A. RICHARDS and R. W. PEARSON, *Iowa State College, Ames, Iowa.*

BOOK REVIEWS

METHODS OF STATISTICAL ANALYSIS

By C. H. Goulden. New York: John Wiley and Sons. VII+277 pages, Illus. 1939. $3.50.

THIS work is the first printed form, revised and enlarged, of a bound mimeograph, two editions of which were issued. A review of the first mimeographed edition was published in this JOURNAL (vol. 28, page 772).

In the preface of the present volume, the author states, "The basis of this book, therefore, is the supplying of a textbook in statistics for students who have passed the elementary stage; who have studied a fair amount of theory and principles and now wish to equip themselves for actual statistical work in their own field of research activities." This statement excuses the author for only briefly considering the theory of statistics and for omitting discussion of experimental technic such as selection of test areas, eliminating border effects, planting, harvesting, etc. The reader is expected to have secured this groundwork previous to a study of this volume.

The book combines statistical mathematics, chiefly the phase usually called "small sample theory", with experimental design. About two-thirds of the book is devoted to the former and one-third to the latter subject, if we are guided by the contents of the usual books on these subjects. It must be admitted that both these phases are intermingled in many parts of the work. While the review of statistical mathematics is concise, well-balanced, and illustrated by numerous worked examples all of which reflect to the credit of the author, the reviewer believes that experimentalists, especially those concerned with field tests, will welcome especially the chapters dealing with experimental design because (1) a considerable amount of this subject matter is not found in other American works; (2) the author has brought together pertinent material, much of which is

scattered through the literature; (3) the selections have been carefully made; and (4) each type of design selected has been illustrated by an example carefully worked out and clearly expressed. Furthermore, the student who wishes to investigate the subject more fully will appreciate the references to the literature given at the end of each chapter.

The chapter headings include Calculation of the Arithmetic Mean and Standard Deviation—Frequency Tables and Their Preparation; Theoretical Frequency Distributions; The Design of Simple Experiments; Linear Regression; Correlation; Partial and Multiple Regression and Correlation; The X^2 (Chi-square) Test; Tests of Goodness of Fit and Independence with Small Samples; The Analysis of Variance; The Field Plot Test; The Analysis of Variance Applied to Linear Regression Formulae; Non-linear Regression; The Analysis of Covariance; and Miscellaneous Applications (includes the estimation of missing values and methods of randomization). Tables of t, Chi-square, and F and an index complete the volume.

Because of their importance, reference should be made to the subjects covered in the chapter entitled "The Field Plot Tests", *viz.*, General Principles and Standard Designs, including the sub-titles soil heterogeniety, replication, randomization, error control, randomized blocks, the Latin square, factorial experiments, split-plot experiments; Confounding in Factorial Experiments, including orthogonality and confounding, partial confounding and recovery of information, splitting up degrees of freedom into orthogonal components, confounding in a 3 x 3 x 3 experiment, partial confounding in a 3 x 3 x 3 experiment; and Methods for Testing a Large Number of Varieties, including incomplete block experiments, two-dimensional quasi-factorials with three groups of sets, three-dimensional quasi-factorials with three groups of sets, and symmetrical incomplete block experiments. The printing is excellent and the book is well bound. (F. Y. H.)

BOTANY

By William J. Robbins and Harold W. Rickett. New York: D. Van Nostrand Company. Ed. 3. XI+658 pages, illus. 1939 $3.75.

THIS edition follows closely the plan of the second edition. The subject matter has been brought more nearly up-to-date and many new illustrations have been included. In order to make the subject more interesting to the lay student the presentation starts out with a study of plant growth instead of a study of its cellular structure. The book was written for use of general students and is not intended as a foundation for professional botany. The elementary course in botany gives a clear understanding of biological principles to students who do not intend to go on with a study of biological sciences.

Part I deals with the living plant. A discourse on growth is followed with chapters on the structure, foods and nutrition responses, reproduction, heredity, and nature of life of plants. Part II, on the kinds of plants, gives a clear and concise discussion of the plant groups.

The student should become acquainted with the characteristic life cycles and importance of representatives of each group. Final chapters treat of the origin and evolution of life and the distribution of plants on the earth.

Questions for review and discussion along with references are given at the end of the book. These are designed to help test the student on his mastery of the subject.

The excellent manner in which the subject is presented cannot help but acquaint the student with the fundamental physiological process of living things along with their structure, and with the variety and extent of the plant kingdom. Fundamental principles of reproduction, inheritance, and evolution are presented in such a manner that a student should obtain a concise idea of the meaning of life as illustrated by the plant kingdom. (O. A. R.)

ELEMENTS OF STATISTICAL REASONING

By Alan E. Treloar. New York: John Wiley and Sons, Inc. XI+ 260 pages, illus. 1939. $3.25.

THE chapter headings of this book are Numerical Description; the Law of Frequency Distribution; Typical Values; the Measurement of Variation; Moments and Distribution Characteristics; the Normal Curve; Bivariate Distribution and the Coefficient of Correlation; Rectilinear Regression; Residual Variation; Errors of Random Sampling; Sampling Errors of the Correlation Coefficient; Proportions and Probability; the Proportions of Vital Statistics; Sampling Errors of Proportions; the Measurement of Frequency Discordance; and Independence and Bivariate Tables of Frequency. The Appendix includes a table of normal curve functions; tables of z as a function of r; a graph of probability levels for r when ρ is zero and N is small; a table of the probability integral of χ^2; and selected formulas. An index completes the volume. No bibliography is included.

Textbooks dealing with statistical methods vary much in the proportion devoted to explanation or logic of each phase of the subject and that used to show the methods of calculation. At one extreme are books in which very little descriptive matter is presented with most of the text given to algebra and arithmetic. In fact these might well be called computers handbooks. The majority of American works on statistics contain about equal amounts of descriptive matter and of computation. The present volume goes to the other extreme by making the logic of statistics the main theme, using worked examples to illustrate the theory discussed. Thus, the author follows the plan used by many British and European writers. His aim is to cultivate in the student, "a keen appreciation of the analytical power in quantative logic which a knowledge of mathematics may open to him." This viewpoint is epitomized in the preface where it is stated, "What is written herein is intended for those who wish to reason carefully, not merely imitate".

Dr. Treloar has written a logical, condensed book that carries out his aims for the phases of the subject selected and has produced a

work that should greatly assist all investigators who wish to make the best use of statistical methods in the interpretation of their results. Unfortunately, the author for reasons of economy has felt compelled to present only certain phases of the subject. Small sample statistics have been omitted entirely. Although the book is limited to large sample theory, a number of important subjects belonging to this group are not included, the most prominent being partial and multiple correlation. It is hoped that the reception of the present book will warrant the publishing of a second volume covering all these subjects.

The book is an excellent text for those who desire to secure an up-to-date foundation in large sample theory, although the beginner will find it advantageous to supplement his studies by the use of other works that give more drill in calculation if he desires to become proficient in the subject. The format, press work, and binding are excellent. (F. Z. H.)

RESEARCH AND STATISTICAL METHODOLOGY

By Oscar Krisian Buros. Rutgers, N. J.: Rutgers Univ. Press. VI+ 100 pages. 1938. $1.25.

THIS work is claimed to be an effort to make available sources and excerpts from critical reviews of all books in the English language in which research or statistics constitute the main theme and which appeared during the interval 1933 to 1938. Most of the references are to works on statistical methods and to manuals for preparing reports and writings on scientific subjects. It is true that a number of books dealing with methods used in some branches of natural science are considered, but works of other branches seem to have been neglected. Chemistry is an example.

A shortcoming, that appears to be important to the reviewer, is the fact that no very complete guide to the contents of the books reviewed is furnished. In many instances a list of the chapter headings were given in the original reviews, but these have been omitted in the excerpts. The reviewer realizes that to have included these tables of contents would have increased the amount of printed matter considerably, but it would have been possible to have coded the subject matter so as to have given the reader a better idea of the contents of each book without unduly increasing the amount of printed matter in the present volume. The Classified Index is helpful but lacks the completeness necessary for the reader to make a selection of all the books in which some special subject is discussed, as for example, tetrachoric correlation or parabolic regression. It is hoped that in future works of this nature some economical, specific, and practical method will be adopted to carry out this idea.

There is much to commend in the work, however, since the excerpts from reviews give the reader the opinions of others regarding any particular work and, although incomplete, some idea of the subject matter is afforded. (F. Z. H.)

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THE AGRONOMIST, HIS PROFESSION, AND AN EXAMPLE OF COORDINATED RESEARCH[1]

RALPH J. GARBER[2]

THE agronomist is truly at the crossroads of agriculture. There passes within view of his vantage point almost the entire panorama of agricultural production. Well nigh every item of human food and clothing has, somewhere along the line from its source to its final synthesis, challenged the interest of an agronomist. Our good friends the horticulturists would likely not admit that the domains of soil tilth, soil organic matter, soil moisture, and soil productivity are exclusively those of agronomy, but I think they would admit readily enough that in the solution of problems involving these factors as they relate to the growth of fruits and vegetables, the agronomist's aid has frequently been sought and received.

The agronomist not only occupies a position that is fundamentally important in agriculture, but in industry as well. Much industrial production is dependent upon successful crop production. Problems of land use adjustment and soil conservation which affect both urban and rural peoples require the guiding hand of an agronomist to help in their solution. One might go on and cite innumerable instances where the interest of an agronomist impinges upon and affects those of his fellow man, but this is unnecessary.

THE AGRONOMIST

With such a range of interest, what sort of an individual is an agronomist? Zoologists tell us he belongs to *Homo sapiens* (but let me hasten to add that the first part of the specific name, "s-a-p", has no sinister connotations). This classification, in common with other men, places agronomists in the same general family with monkeys. Please note that I am not even remotely referring to the possible relationship between men and monkeys, but simply pointing out to you the particular pigeon hole into which experts on the classification of animals have thrust the agronomist. I am very eager to make this

[1]Presidential address presented before the thirty-second annual meeting of the Society, New Orleans, La., November 23, 1939.

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point clear, if for no other reason, than that I do not wish to start an argument that might well engage our wits and prejudices for days without end.

The cytologist tells us that each cell of an agronomist contains 24 pairs of chromosomes that comport and disport themselves as only such bodies can. He assures us that one member of each pair is paternal and the other maternal in origin. He also advises that one of the 24 pairs has a peculiar significance for us. I refer to the sex chromosomes. If our paternal ancestor had given us an x-chromosome, instead of a y-chromosome, we would have been more likely to become an agronomist's helpmate than an agronomist. Be that as it may, these 24 pairs of chromosomes have played a very important role in determining the final product, man, for they are the bearers of genes, the fundamental units of heredity, if not of life itself.

In our primordial existence and later throughout life these chromosome pairs behave with a nicety that is truly astounding. Just previous to the formation of eggs or sperm, corresponding members of chromosome pairs may exchange comparable segments, then disjoin so that each egg or sperm that is eventually formed is allotted 24 chromosomes—one member of each pair contained in the body cells. When the egg is fertilized with a sperm the normal number of chromosomes, 48, is restored. From this original fertilized egg throughout life, each cell division characteristic of growth is preceded with a splitting of each chromosome to form two new chromosomes; thus, the mechanism is provided that assures each descendent cell its normal complement of chromosomes.

As may be inferred from what has already been said the chromosomes in themselves would not be of such great importance if it were not for the fact that they carry the hereditary factors. This is the opportune moment to call in the geneticist, or "gene chaser", as he is sometimes inelegantly, but quite descriptively, called. He tells us that each chromosome contains scores, if not hundreds, of genes. If this is true—and the veracity of the geneticist is seldom questioned—it may be of interest to pause and reflect a moment on the possible diversification of natural endowments among incipient agronomists. If we assume that each chromosome carries but a single gene, there would be possible a total of 282,429,536,481 different combinations as a result of disjoining and rejoining independently 24 pairs of chromosomes. From this it is easy to see that even if we assume but a few genes in each chromosome there is little likelihood of finding two agronomists alike in anything except perhaps in subject matter interest.

Where does this dilution of sense with a bit of nonsense lead us? I hope it will serve to show that the scope and functions of the agronomists are broad and varied, but fortunately agronomists collectively represent an array of talents fully capable, when harmoniously symbiotic, of handling successfully the many agronomic responsibilities.

THE AGRONOMIST'S PROFESSION

Agronomy comprises several of the so-called pure sciences anastomosed. It is concerned with growing bigger and better crops more

efficiently, without at the same time losing the soil, that most valuable aid in man's struggle for the elusive "abundant life". Early in our history it was not uncommon for a single agronomist to have under way experiments dealing with crop rotation, tillage, variety testing, fertilizers, and plant selection, to say nothing of his teaching and extension duties. In those days the agronomist was truly a man of broad intersts. I am somewhat fearful at times, in our present era of intensive specialization, lest we lose perspective and balance in our agronomic investigations. Perhaps we should maintain general experimental farms to determine how well new procedures and improved varieties fit together to make a successful farm enterprise. In this connection I would like to commend for your later attention the Presidential address of R. G. Stapledon, Director of the Welsh Plant Breeding Station and Imperial Bureau of Pastures and Forage Crops, delivered before Section M (Agriculture) of the British Association for the Advancement of Science and published in Volume 6, Number 3, of the Herbage Reviews for 1938. I shall content myself at this time with a brief quotation from page 141:

> "The major aim of agronomical research, which is essentially field research, is to study all the factors which are operative at once and together, and in their natural interplay, for 'nature is a theatre for the inter-relations of activities'. Such a procedure, it may be said, is impossible or at least unscientific. It is certainly not impossible, and if it is unscientific it will yet remain agronomical, and many of the problems of agriculture are more likely to be solved, shall I say, by agronomical investigations than by scientific research, while nearly all the results of scientific research have to pass through the sieve of an immense amount of agronomical investigations before they can be other than positively dangerous to the practitioner."

While we may sometimes dream in retrospect and express a yearning for some of the good things of the past, we are all fully aware that agronomic progress has come about through agronomic specialization. We are no longer content with trial and error methods, we are interested to know why a thing happened as well as to know it did happen.

Agronomy for the most part has changed from a profession of generalists to one of specialists and incidental to this transformation has become more analytical and perhaps less synthetical. The tendency now is for the research agronomist to analyse his problems in terms of soil chemistry, soil physics, soil microbiology, cytogenetics, or physiology, and evaluate and interpret experimental data relative to the solutions of these problems in definite quantitative terms. Methods both in the laboratory and in the field have been greatly improved.

As an example of progress in methods one may cite the evolution of field experiments. It is a long step from the one plot per treatment of a few decades ago to the present two dimensional pseudo factorial arrangement. The results obtained from the earlier experiments were interpreted largely by the use of the personal equation; now we analyze variance with the aid of a calculating machine to arrive at an entirely impersonal result. Perhaps we have gone too far in this di-

rection. Certain agronomists have been so unkind as to suggest that a sort of statistical phobia has supplanted common sense. Be that as it may, I think even the most rabid anti-anything-statistical would admit that mathematical analysis has had a profound influence in the refinement of field experiments.

At one of the recent annual meetings of our Society an eminent plant physiologist expressed surprise at the high level of plant physiological understanding among agronomists. In a different session of the same meeting a well-known geneticist, in opening a symposium before a group of plant breeders, explained at great length some of the modern genetic viewpoints and inferred that the group was unfamiliar with them. He soon discovered to his chagrin that the explanations were unnecessary and the inference incorrect.

The soil agronomists have gone even further than the plant agronomists in specialization as evidenced by the following self-imposed classifications: soil physics, soil microbiology, soil genesis, morphology and cartography, soil chemistry, soil fertility, and soil technology. I presume soil conservation might be added; or is the activity under this category as yet too broad to be called specialized?

With all these ramified and somewhat diverse interests within the agronomic fold, I submit that no one agronomist is learned enough to be a master in each field or broad enough to see all angles of an agronomic problem. I suspect that extension agronomists more than any other group feel the need of tieing together and interpreting for practical farm conditions the many technical results being made available to them by the research agronomists. What are we going to do about this situation? I am not conceited enough to think I have the final answer, but with your permission I would like to describe briefly a cooperative attempt to coordinate and integrate pasture research in the northeastern states as an example of one way to facilitate the convergence of divergent approaches toward a single objective.

AN EXAMPLE OF COORDINATED RESEARCH

The directors of the twelve agricultural experiment stations in the northeastern United States have been holding annual meetings for many years to discuss problems of mutual interest. When the funds under Title I of the Bankhead-Jones Act of 1935 became available this group recommended that a laboratory for pasture research be established somewhere in the Region. After a survey of the available sites it was decided to locate such a laboratory at State College, Pennsylvania. The functions of the laboratory, which is financed by Bankhead-Jones funds assigned to the Bureau of Plant Industry of the U. S. Dept. of Agriculture, are to serve as the focal point for coordinating and integrating pasture research in the northeastern states and to carry on fundamental research not already adequately provided for in the Region. I have used the words "to serve as the focal point" advisedly and purposefully, since this is a democratic, not a totalitarian venture.

SOME AGRICULTURAL CHARACTERSITICS OF THE NORTHEAST

Before detailing some of the more significant steps in this enterprise it may be well to describe very briefly some of the pertinent agricultural characteristics of the Region. The soils for the most part are of glacial origin, although residual soils derived largely from limestone, shales, or sandstones are found in certain areas, particularly in Delaware, Maryland, New Jersey, Pennsylvania, and West Virginia. The soils vary from light sands to heavy clays and from unproductive to highly productive ones. The topography varies from narrow plains and valleys to hills and mountains. Much of the area is woodland, or cut-over woodland that should be replanted to trees. Other large areas are suited primarily to a grassland type of agriculture. The precipitation is usually adequate for luxuriant growth, although during July and August the weather may be dry and hot. The northeastern United States embraces one of the most important milk-marketing regions in the world, both from the standpoint of production and consumption.

Pasture, when available, is the most economical source of feed for the dairy cow so perhaps the most important pasture problem is to provide adequate herbage for grazing throughout the entire growing season. Increased production at a lower unit cost, improved quality, and greater palatability are other important considerations. The solution of these problems is complex and demands a diversified approach. Moreover, pasture research men in the northeastern United States, while in essential agreement as to the objectives to be attained, differ widely in opinion as to the most effective methods of attaining those objectives. From a research point of view this is a stimulating situation but at the same time one that requires a cooperative approach if the research is to be coordinated. This is perhaps the strongest reason why the directors of the twelve northeastern states urged the establishment of a regional pasture research laboratory.

A PLAN FOR COORDINATION

A memorandum of agreement was drawn up, setting forth in broad terms the objectives of the Laboratory and the respective responsibilities of the Bureau of Plant Industry of the U. S. Dept. of Agriculture and the twelve agricultural experiment stations concerned, i.e., Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and West Virginia.

To effect a close coordination in the pasture research of the Region, a collaborator was appointed to represent each state station cooperating with the Laboratory. The collaborators meet annually with the Laboratory staff and other representatives of the U. S. Dept. of Agriculture to help plan, coordinate, and integrate fundamental pasture research in the northeastern United States regardless of whether the work is supported by state funds, federal funds, or both.

As a guide in furthering this undertaking a statement of policy was drawn up and mutually accepted by the agencies concerned. I shall not attempt to repeat the full statement at this time, but some of the more significant features may be of interest.

It was agreed that all phases of the current pasture research projects, which are likely to yield information of regional interest, would be reviewed with a view to determining their suitability or to modifying them to fit into a coordinated plan. It was not the intention, of course, to assume direction over the work of any station. The idea was merely to analyze frankly and to plan a coordinated program on the fundamental aspects insofar as such action is practicable from an administrative standpoint. Any recommendation made by the collaborators which involves the discontinuance or initiation of a major line of pasture research in a given state will first be reviewed and passed upon by the director of that state station and by the administration of the Pasture Laboratory before it is made a part of the regional research program.

It was agreed that the Laboratory's researches should pertain particularly to lines not already adequately provided for and directed along lines most likely to yield information of regional interest. Similarly research conducted in cooperation with a state station should be of the type likely to yield basic information. If the Laboratory develops new strains or strain combinations of pasture plants or discovers new facts which appear to possess merit from the farmers' standpoint, they should be thoroughly tested in cooperation with state workers, who, in this case, preferably would assume the major responsibility for carrying on the work.

During the somewhat more than two years of the Laboratory's existence the collaborators have held three meetings and have sponsored two meetings of plant breeders interested in pasture improvement in the Northeastern Region. Frequent exchanges of professional visits among individuals engaged in pasture research in the Region have been promoted, in addition to the occasional group meetings. Any instrumentality which will serve to bring research men working in similar fields together to become better acquainted, both professionally and personally, is useful, since one of the greatest obstacles to overcome in promoting cooperation and coordination is mutual misunderstanding.

The collaborators have facilitated a free exchange of project outlines dealing with pasture research between the State stations and the Laboratory. All project outlines of the Laboratory are kept up to date and filed with each cooperating State station. Likewise, the project outlines of the State stations are on file at the Laboratory. The annual report of the Laboratory, a copy of which is sent to each cooperating agency, includes also a progress report of the pasture research under way at each State station. The collaborator is responsible for assembling this material at his particular station.

As a more or less direct outgrowth of these activities cooperative projects have been drawn up under which certain state stations and the Laboratory are cooperating in a breeding program. In these projects the Laboratory is giving most of its attention to the fundamental aspects underlying methods of breeding, whereas the state stations, in addition to some of the fundamental aspects, are giving particular attention to breeding with the definite objective of producing improved strains for the particular conditions under which they are to

be grown. This kind of cooperative arrangement seems necessary to make effective progress. With a Region as diversified in soil and climate—to say nothing of variation in pasture management practices—it is hardly reasonable to expect that a centrally located laboratory, even though it were physically possible to do so, could breed improved forms for the whole Region. Moreover, in such a comparatively new field there is need for pioneering in ways and means of bringing about improvement by breeding and it seems logical that the Laboratory should devote a considerable share of its attention to this phase of the work.

In addition to this more or less formalized approach to research on a regional basis, informal methods are likewise encouraged. An example may be cited. Two project leaders in the Region, one at a state station and one at the Laboratory, discovered through an exchange of letters, that they were contemplating similar composition studies of pasture grasses. By mutual agreement it was decided that one of them should study one species and the other another species. By correspondence and occasional personal conferences, these two men are keeping in close touch with the progress of one another's work. Such an arrangement, it seems to me, is one of the most effective means of coordinating research.

I have used the terms cooperation and coordination with a slight difference in meaning, a difference primarily of degree. It is generally true that we cannot have coordination without cooperation; it is particularly true in attacking a problem so involved and with so many possible angles of attack as has pasture improvement in the northeastern states. On some phases of this problem it may be mutually advantageous for two or more stations, state or federal, to carry on a specific research project in close cooperation with one another. On the other hand, in some cases it may be more expedient for individual stations to assume major responsibility for developing certain phases of the problem and thus, by concurrence, bringing about effective coordination.

I like to think of our regional approach to pasture improvement in the northeast as an arrangement whereby all research facilities, including both personnel and available equipment, regardless of the funds supporting them, are brought together, scrutinized, appraised, and, by mutual agreement, guided and made use of along the respective lines which seem most effective toward achieving the common objective—acquisition of the facts underlying pasture improvement in the Region concerned.

RESEARCH AT THE LABORATORY

What I have said about the approach to pasture research on a Regional basis applies equally well to the research of the Laboratory itself, but on a smaller scale. We have brought together at the Laboratory a number of research specialists with different viewpoints and training, but all with a common objective—contributing something of regional interest in pasture research. At present the group includes a physiologist, a soil chemist, two cytogeneticists and plant breeders,

a biochemist, and a plant pathologist. These six project leaders are working on the same pasture species, but from different angles.

The research of the laboratory is organized around two main-line projects, (1) cytogenetics and breeding and (2) physiology. As source material thousands of individual plants of the important pasture species are being grown in the nursery. This material came from both seeds and plants collected in pastures of the Northeast, as well as from seed from important producing areas in the United States, Canada, and other countries.

The breeding and cytogenetic investigations have for their immediate objectives the discovery of fundamental facts helpful in planning an intelligent breeding program and the isolation and cataloging, with respect to specific characteristics, of more or less true-breeding strains. At present the cytogeneticists are concerned with such questions as self- and cross-compatibility, effect of inbreeding, chromosomal relationship to plant characters and behavior, species crosses, the efficacy of colchicine in producing chromosomal reduplication, and methods of evaluating, for pasture purposes, individual plant types.

In the physiological studies emphasis is being placed on temperature and water relations to plant growth, the relation of intensity and duration of light to fruiting and vegetative growth, and plant food reserves in the underground parts in relation to top removal and fertilizer treatment. The responses of different clones of the same species to different nutrient levels both in soil cultures and artificial gravel media is receiving considerable attention. In the composition studies the variation among individual plants of Kentucky bluegrass with respect to crude protein and among individual plants of white clover with respect to certain minerals are being determined. The cyanogenetic glucosides of white clover and the carbohydrate fractions of some of the grasses are other subjects under investigation.

The pathologist is working in an almost virgin field in the pasture plants. Of necessity, he at first is concerned with a survey to determine what are the most destructive diseases in pastures. He must work out life histories of the pathogen so as to enable him more intelligently to plan control studies. In the pasture species practical control of diseases is most likely to come from breeding for resistance, hence the pathologist must work out methods of inducing artificial epiphytotics so that he and the plant breeder, working together, may make effective progress in breeding for resistance.

One of the fundamental problems in which the Laboratory is interested is variation, either natural or induced, within pasture species. Perhaps I can illustrate an approach to this problem in one species by citing an actual example. The plant breeder is studying 81 different plants of Kentucky bluegrass asexually increased in sod plots as a first step in determining their potential pasture value, the cytogeneticist is investigating their method of reproduction, the soil chemist is studying the response of some of these same clones to different levels of phosphorus and nitrogen fertilization in soil cultures in the greenhouse, the physiologists are studying the relative effectiveness of water utilization of some of the clones and making a survey of the

variation in their crude protein content, and, finally, the plant pathologist is determining their relative resistance to Helminthosporium "leafspot". If time permitted, I could cite other examples of similar nature, but I think this one suffices to illustrate coordinated and cooperative research among members of the Laboratory staff.

In closing I offer my apologies for protracting this example of coordinated research to such a length and for the rather frequent digressions. If there is a grain in the chaff which I have winnowed before you it is the challenge to accept the ever-widening agronomic responsibility by effective cooperation.

THE HAZARD OF BASING PERMANENT GRAZING CAPACITY ON *BROMUS TECTORUM*[1]

George Stewart and A. E. Young[2]

DATA obtained during the 1937 and 1938 grazing seasons in Gem County, Idaho, make clear the extremely great economic hazard and the management difficulties involved when the perennial grazing capacity is based on the fall-annual grass downy chess (*Bromus tectorum*) locally known as cheatgrass. This hazard consists largely of two elements, somewhat related to each other but still more or less distinct. They are (1) the wide variations in forage production from one year to another, and (2) the uncertainty as to whether there will occur any production great enough in volume to serve as a basis for livestock grazing. These statements deal with both relative and absolute values and derive most of their importance from the comparison between downy chess and the perennial plant species that only a few years ago constituted most of the plant cover on this area and yielded most of the forage for livestock.

ECOLOGICAL HISTORY

A brief review of the ecological history of downy chess and of the part it plays in the grazing economy of the Intermountain region will help to clarify the nature of the difficulty that has arisen as a result of native perennial forages having been largely replaced by downy chess on many millions of acres of foothill ranges. About 1900—no records are available to establish the definite date—downy chess appeared in northern Utah and began to increase in places where the plant cover had been disturbed, as along roadsides, fence lines, and in old stands of alfalfa. This grass also spread to uncultivated areas, especially where the cover of native perennials had been thinned or so reduced in vigor that there was less than a full natural stand. Large areas of foothill range and adjacent valley edges that had been grazed without restriction by community livestock were soon occupied.

Ranges formerly furnishing some feed throughout much of the summer now bore after the end of June only the tough, straw-colored stalks and hard-toothed seeds of downy chess, dead dry, and highly inflammable. Frequent fires raced over these foothills, and owing to the slenderness of the pedicels bearing the spikelets, these burned through and the seeds dropped to the ground uninjured by fire. The seeds and root crowns of perennial grasses, however, are sometimes injured because the more abundant growth holds the fire longer. During a fire most woody plants are consumed down nearly to the ground line. After a few years these fires, together with unrestricted grazing, brought about nearly pure stands of downy chess. When no fires occurred the seeds shattered and were dispersed naturally.

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Autumn rains enable the downy chess seeds to germinate and the seedlings to develop considerable grass clumps before the coming of snow, under which they lie dormant until spring. The first warm days stimulate the growth of leaves and flower stalks which proceeds with great rapidity by vitrue of the root and crown development of the previous autumn. This early growth furnishes spring feed for livestock but lasts only about four or at most six weeks before the soft green growth dries and toughens at the time of seed development. In another 3 or 4 weeks the seasonal cycle is completed and during July and August the matured, dry plants are seared with summer heat, and being annuals they show no further activity until fall rains germinate the seeds and start a new crop of seedlings.

The growth of downy chess is markedly affected by both temperature and available moisture at two critical periods, (a) in the fall when seed germination ordinarily takes place and vegetative stooling begins, and (b) again in the spring when flower stalks are sent up and most of the volume of top growth is produced. Should autumn precipitation be so nearly lacking that germination does not take place or that clumps are not developed in the fall, or should the spring be so dry or so cold as to retard top growth, the amount of total vegetation produced is very small.

In an unusually late, cold spring top growth may be retarded until the normal time to begin seed production has arrived, after which during long warm days the soil soon dries out and vegetative growth ceases. Sometimes when cold spring weather delays growth and even when moisture is abundant, seed production takes place while vegetative growth is still meager. In the absence of critical studies, definite statements cannot be made as to all the reasons for retarded growth in late springs. Observation and preliminary tests, however, lead to the opinion that downy brome is so strongly influenced by the length of the daylight period that when the required day length occurs seed production sets in almost irrespective of the height or spread of the vegetative growth. At any rate, in some years heavy seed production occurs on greatly dwarfed plants, though in most years vigor of top growth and high seed production accompany each other.

DISTRIBUTION AND ECONOMIC IMPORTANCE

Downy chess has spread throughout Utah in the intermediate foothill zone, being abundant neither at the high elevations where mountain plants prevail nor in the dry desert valleys where Russian thistle replaces it as the predominant annual on abandoned cultivated land and in the spaces of a weakened plant cover that were formerly occupied by native desert perennials. Downy chess is particularly abundant in the foothills of the Snake River Valley, and especially so in the 200-mile northwest-southeast stretch in which Boise, Idaho, is about centrally located. More recent is its occupation of Nevada, of eastern Oregon and Washington, and of Montana in parts of which it is thought to be still invading.

In Montana particularly, stockmen and staff members of the Montana Agricultural College have within the past few years ex-

hibited considerable concern about its further spread. Many stockmen of the Intermountain region also fear that once downy chess has occupied a tract of range land that perennial forage cannot be brought back. Opposed to this fear is the fact that, on several areas supporting a vigorous growth of native perennials, downy chess has invaded but has not thickened its stand materially.

Critical research is much needed in order to determine under which ecological conditions perennial forage species may be able to invade established stands of downy chess and the rate at which the perennials may become established in the area. Perhaps the competitive superiority of one plant group over the other may differ under differing environments. For example, in the foothill zone of northern Utah and southeastern Idaho where the annual precipitation is 9 inches or more, perennial forages are apparently increasing in downy chess areas on which for a few years grazing has been relaxed and fires kept out. In other words, the better native perennial forage species seem likely, when given a fair opportunity, to be able under fair precipitation to compete successfully with downy chess.

On the other hand, many good observers are of the opinion that where the precipitation is 6 to 8 inches or less, perennial vegetation is not sufficiently vigorous to enable it to replace downy chess, even when the area is very lightly grazed. Many other workers think that in time perennials would return. Unanswered questions have been raised as to whether perennials can in ordinary circumstances make good headway in stands of downy chess; whether in arid conditions such replacement would not be so slow as to make it inadvisable to sacrifice the spring growth of downy chess in order to give the perennials a chance; and whether, as some think, the downy chess is as valuable for forage as the perennials that can be restored under conditions which are unfavorable to the perennials.

The competition between downy chess and native species has taken a new departure in some parts of the region during the last few years, a form of smut (*Ustilago bromivora*)[3] having attacked downy chess but not the native grasses. For example, in 1935 and 1936 this smut was so abundant on the foothill range to the north of Mountain Home, Idaho, that scarcely any seed was produced in that area, greatly relaxing the competition with perennial forages where these were abundant enough to take advantage of the open spaces in the plant cover.

Downy chess, though a much used grazing plant, is not in the true sense highly palatable. Its value for grazing is limited greatly by the fact that the leaves are both hairy and sparse, and that the period during which it is fresh is short. As the time of seed maturity approaches its stems become tough and wiry and its seeds hard with toothed lemmas, often lodging in the softer tissues of the mouths of livestock, particularly of young animals. In warm moist springs, however, for about a month before seed begins to develop and the stems get tough, the leaves and early stem growth are eaten readily by both cattle and sheep, as is also the new growth that springs up in autumn after good rains. Horses have been shown to be able during

[3]U. S. Forest Service Range Plant Handbook, sheet G38 (1937).

summer nearly to maintain themselves in good condition of flesh and liveliness when they had access to an abundance of pasturage consisting of 89% of dried herbage and seeds of downy chess.[4] The many millions of acres of spring and fall range occupied by it and the extreme scarcity of perennial grasses make it a highly important feed. In fact, it is so much used during the range lambing season that many stockmen regard it as their principal source of spring feed. This tends to obscure the importance to stockmen of restoring the good perennial grasses which are more palatable, produce higher yields of forage, do not have toothed seeds, and keep soft for 8 to 12 weeks in comparison with 4 or 6 weeks for downy chess. The completeness with which downy chess occupies a favorable area greatly retards, though under ordinary precipitation it probably does not prevent, the increase of perennials. The abundance of downy chess, however, increases the fire hazard, and thereby tends indirectly to keep out perennials altogether.

RANGE SURVEY OF GEM COUNTY, IDAHO

During the summer and fall of 1937 an interagency range survey, known officially as the Western Range Survey, was conducted in the western United States. As part of this survey, Gem County in Idaho was completely covered and several other Idaho counties partly covered. For Gem County a vegetation type map was prepared and the forage inventoried at the minimum survey intensity of 10 plots to the section by the point-observation-plot method.[5] From this survey, grazing capacity in cow-months was calculated and tabulated on a map within vegetation types by sections. As a whole, the reported grazing capacities were much lower than was thought to be correct by the stockmen who were using these lands, and who were to be allowed A.A.A. benefit payments in proportion to the grazing capacity of their range lands.

When the time for the next grazing season was at hand, it was clear that the grazing capacity for 1938 was much higher than that reported for 1937. This led to a re-examination of the area by the Intermountain Forest and Range Experiment Station. The procedure consisted of visiting about 20 typical areas in the county and examining such areas closely, after which forage conditions on a larger surrounding area were noted in a more general fashion. By far the greater part of the vegetation on most of the re-examined areas was found to consist of downy chess, with which was interspersed a few annual weeds, and in some parts of the area, a very sparse but well-distributed cover of bunch bluegrass (*Poa* spp.). The forage production in 1938 was therefore tabulated as a distinct reading and compared with the WRS map showing the grazing capacity of 1937 as another distinct reading. Since a new range survey was not possible, and since, as

[4]HURTT, L. C. Downy brome (cheatgrass) range for horses. Applied Forestry Notes (mimeographed), Northern Rocky Mountain Forest and Range Experiment Station, January, 1939.

[5]STEWART, GEORGE, and HUTCHINGS, S. S. The point-observation-plot (square-foot density) method of vegetation survey. Jour. Amer. Soc. Agron., 28:714–722. 1936.

compared with an entirely new forage inventory, it was much quicker to arrive at an approximation of the 1938 grazing capacity by comparing it with that of 1937 as shown on the WRS map, the 1938 forage production is expressed by a percentage figure that indicates the amount by which it exceeds that of 1937.

PRECIPITATION AND FORAGE GROWTH

The more abundant protection of downy chess in 1938, as compared with that of 1937, is accounted for by several climatic conditions. The precipitation in 1938 was about double that of 1937 and the 1938 crop was further helped by approximately 5 inches of precipitation during the three fall months of September, October, and November 1937, when downy chess was beginning growth, as compared to practically none during the same months of 1936. These data and also the fact that the spring rainfall of March, April, and May when this grass grows most rapidly was about 75 to 80% greater in 1938 than in 1937, are shown in Table 1 and Fig. 1. During the cold, snow-covered winter of 1936–37 little germination and practically no growth took place until March; whereas, during the mild, rainy winter of 1937–38 full germination occurred in September and growth continued almost without cessation from that time till the seed matured in June.

This timely and abundant precipitation and the open winter so favored the growth of downy chess that the grazing capacity in 1938 was much higher than that obtained for 1937, owing largely to the increased production of downy chess, but in a minor way to some forage production by native bunch bluegrasses not reported in the 1937 survey. These grasses were missed at that time because of their dry scorched condition in the late summer when they are normally dormant. The local Soil Conservation Service workers had already found the bluegrasses and had arrived at the same conclusions with reference to increased grazing capacity, having taken a considerable number of check estimates on typical areas of the county.

A careful examination of the forage on the ground, of the data which the Soil Conservation Service had taken, and of the additional information gathered at the time of the check survey, all show the tremendous variation in the forage produced from one year to another and from one small area of land to another by the annual downy chess. This plant is the only annual plant in Gem County requiring much consideration in this study, but it is thought that the same wide variation would occur in almost any area in which either this plant or another annual constituted most of the plant cover, and had been subjected to as great a variation in the total quantity of precipitation and in the distribution of that precipitation as occurred in Gem County when 1938 is compared with 1937. Perennials also vary widely in forage production from year to year but as will be seen they were much more dependable than annuals in Gem County.

DATA OBTAINED BY RE-EXAMINATION

Three general soil conditions prevail in Gem County, namely, (1) loose granitic sands, (2) fine-grained basaltic soils, and (3) ancient

Payette lake-bottom soils. The behavior of the downy chess on these respective soil types was in the main rather distinct. On the granitic soils a luxuriant growth of downy chess was produced in 1938, from 100 to 200% greater than that of 1937, whereas on the basaltic soils the increased growth, though marked, is much less than on the granitic soil, being 40 to 85% greater than that of 1937. On the Payette lake-bottom soils the total growth and the increased production over that of 1937 were greatest of all, the forage production being approximately three to ten times as great in 1938 as in 1937 and averaging five times as great. The weak response of downy chess in 1937 and of the small bunch bluegrasses that were missed altogether because of having dried completely, probably caused the reported 1937 grazing capacity to be somewhat lower than it actually was,

TABLE 1.—*Precipitation by months for the two downy chess growing seasons of 1937 and 1938 at Sweet, elevation 2,450 feet, and Brownlee, elevation 4,000 feet, Gem County, Idaho.*

Sweet			Brownlee		
Month and year	Inches		Month and year	Inches	
August 1936	0.24		August 1936	0.27	
September	—		September	—	
October	— }0		October	0.15 }0.16	
November	—		November	0.01	
December	1.27		December	0.97	
January 1937	2.82		January 1937	3.57	
February	1.38		February	2.48	
March	1.80		March	2.44	
April	1.72		April	2.81	
May	0.90		May	0.80	
June	0.69		June	1.48	
July	—		July	0.07	
Total	10.92		Total	14.95	
August 1937	—		August 1937	0.01	
September	—		September	0.24	
October	1.62 }5.16		October	1.43 }4.92	
November	3.54		November	3.25	
December	3.25		December	4.32	
January 1938	4.07		January 1938	2.83	
February	1.68		February	2.99	
March	3.67		March	5.47	
April	2.80		April	1.27	
May	1.36		May	3.40	
June	0.93		June	1.66	
July	0.90		July	0.82	
Total	23.82		Total	27.69	
	1936–37	1937–38		1936–37	1937–38
Total, Sept., Oct., Nov.	0	5.16	Total, Sept., Oct., Nov.	0.16	4.92
Total, Mar., Apr., May	4.42	7.83	Total, Mar., Apr., May	5.95	10.14

but not markedly so because the plants missed are low producers and thinly scattered.

Since forage production was widely variable in different parts of the area, the range lands in that part of the county below the forest boundaries was divided into 10 districts and the forage conditions for

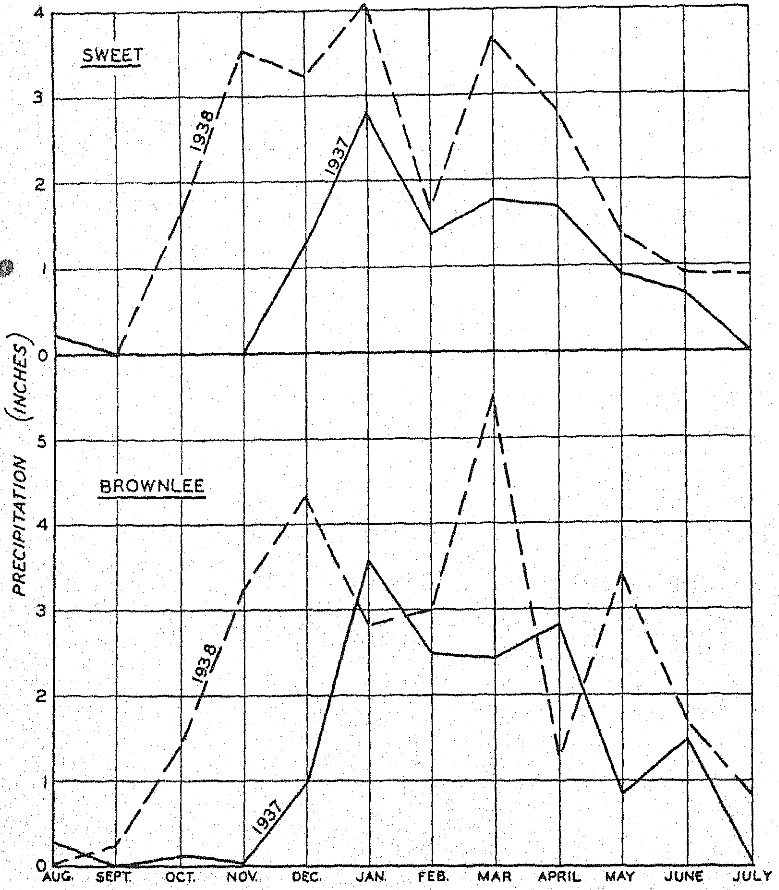

FIG. 1.—Precipitation for two growing seasons of downy chess (*Bromus tectorum*), 1937 and 1938. Since this plant is a fall annual the precipitation of late summer and autumn affects its growth markedly. March and April are the critical months of spring.

each reported separately. The figures are given as percentage additions to the 1937 forage production that are necessary to obtain the forage production for 1938 for respective districts. For example, in district No. 1 a given section of land, i.e., a square mile, having forage for 60 animal-months in 1937 had a capacity greater by 60% of 60, or 36 animal-months, establishing a figure of 96 animal-months for 1938.

The acreages and the percentages by which the 1938 grazing capacity was greater than that of 1937 as shown on the WRS map are summarized by districts in Table 2.

TABLE 2.—*Percentages by which the 1938 forage production exceeded that of 1937 in the 10 districts of Gem County, Idaho, lying below the national forest boundaries and having the kind of soil specified.*

District (nonforest)	Location*	Thousands of acres	Excess of 1938 over 1937, %	Kind of soil†
1	T. 11*, 12*, N.	35	60	Ba
2A	T. 10 N. east of Squaw Creek	10	150	Gr
2B	T. 10 N. west of Squaw Creek	11	85	Ba
3	T. 9 N.	48	200	Gr
4	T. 8 N., E ½; also R. 1 E. and 2 E*	16	50	Ba
5	T. 8 N. W ½ R. 1 E. also E ⅓ R. 1 W.	19	40	Ba
6	T. 8 N. W ⅔ R. 1 W., also R. 2 W*.	22	400	Pay
7	T. 7 N. W ½ R. 1 W.; also 2 W.* and 3 W*	28	400	Pay
8	T. 7 N. E ½ R. 1 W.; also R. 1 E.* and 2 E*	27	100	Gr
9	T. 6 N. W ⅓ R. 1 W.; also R. 2 W.* and 3 W*	22	85	Ba
10	T. 6 N., E ⅔ R. 1 W., also R. 1 E*	35	150	Gr
Total		273	Av. 167+	

Summary by Soil Type

Soil type	District No.	Percentage increase to 1937 to get 1938	Average percentage increase
Basaltic	1, 2B, 4, 5, 9	60, 85, 50, 40, 85	64
Granitic	2A, 3, 8, 10	150, 200, 100	150
Payette	6, 7	400, 400	400

*Signifies only parts of townships included in 1937 map.
†Ba = basaltic soils; Gr = granitic soils; Pay = Payette soils.

An examination of the divergent yields in the 10 districts into which the county was arbitrarily divided shows that it is not possible to give a blanket figure for the entire area of the county, though Table 2 shows a purely calculated weighted average which from the table is seen to apply to not a single one of the 10 districts. The relative amount of vegetation in 1938 as compared with that of 1937 also differed widely and irregularly on various soils, the 1938 forage production being on the average greater than that of 1937 by 64, 150, and 400% for the basaltic, granitic, and Payette soils, respectively. This comparative difference resulted largely from differences in the nature of the soils themselves and in the depth of soil available for root occupation, Payette soils being as a whole several feet deep. Since extremely shallow soils with a depth of only 2 to 4 inches above bedrock, as on many basaltic soils, produce less forage than those

that are 20 to 60 inches in depth, the great variations in production on different areas in the same soil type are easy to explain.

THREE TYPE AREAS

In Table 3 and Fig. 2 are given the data for 1937 and 1938 on three areas, each rather typical, respectively, (1) for nearly pure stands of downy chess, (2) for downy chess intermixed with perennials, and (3) for a stand consisting largely of perennials with a little downy chess.

TABLE 3.—*Forage production in Gem County, Idaho, in 1937 and on the same areas in 1938 on sites fairly representative of areas predominated by downy chess, intermixed downy chess and perennials, and largely perennials with some downy chess.*

	1937		1938	
	Density	Forage acres per 100 acres	Density	Forage acres per 100 acres
Mostly downy chess (T. 8 N., R. 1 W., Sec. 31):				
Bromus tectorum	0.35	0.1225	3.15	1.1003
Poa spp.	Trace	Trace	0.45	0.09
Festuca arida	—	—	0.40	0.28
Total	0.35	0.1225	4.00	1.3803
Mixed downy chess and perennials (T. 7 N., R. 2 W., Sec. 3):				
Bromus tectorum	1.75	0.610	3.50	1.225
Poa spp.	0.50	0.350	0.30	0.100
Festuca arida	—	—	0.50	0.210
Erodium cicutarium	—	—	0.15	0.030
Total	2.25	0.960	4.45	1.565
Largely perennials; some downy chess (T. 11 N., R. 1 E., Secs. 11 and 12):				
Bromus tectorum	0.44	0.154	0.65	0.2275
Perennial grasses	0.89	0.573	2.55	1.6150
Perennial weeds	5.15	0.807	1.55	0.862
Total	6.48	1.534	4.75	2.7045

PERENNIALS VS. ANNUALS FOR FORAGE

The perennial vegetation, a remnant of the original cover which consisted largely of perennial species, is shown in Table 3 to be much more productive as a source of feed, yielding in total volume (2.7045 forage acres per 100 acres) during the favorable year (1938) nearly double as much forage (1.3803) as did downy chess, and in the unfavorable year (1.534 forage acres compared with 0.1225) more than 12 times as much. Perennial vegetation is also much more dependable, producing in the definitely unfavorable year of 1937 approximately the same amount of forage (1.534) as did the mixed perennial-

downy chess area (1.565) in the unusually favorable year of 1938 and 11% more than did the nearly pure stand of downy chess (1.3803). Such wide fluctuations in forage yield when added to the short duration of its availability create in the case of stands of downy chess

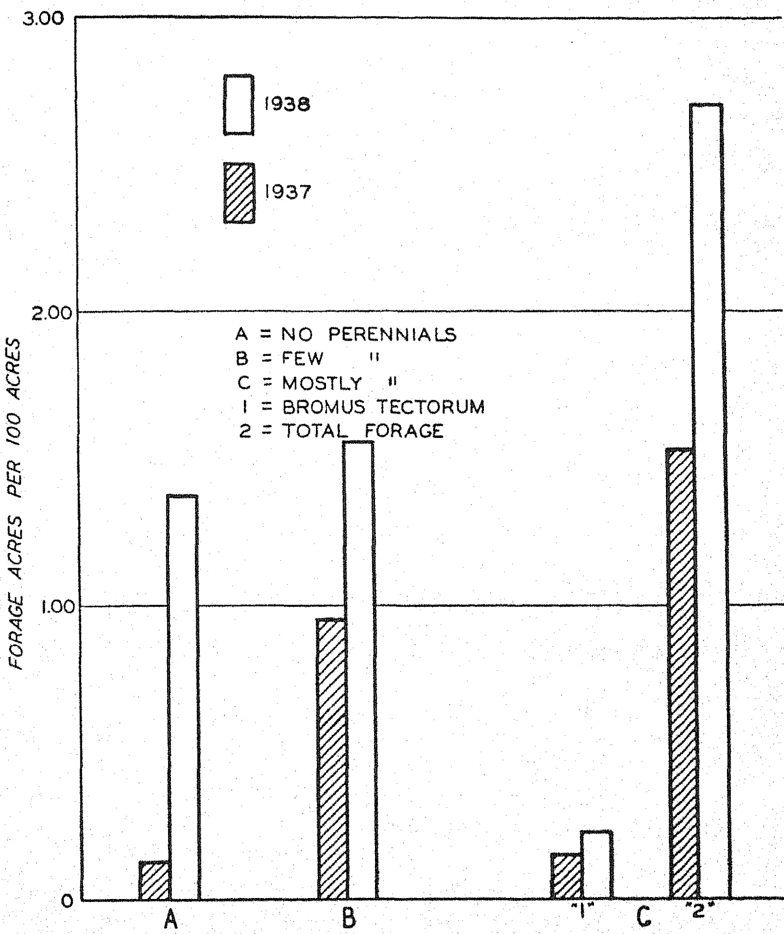

FIG. 2.—Forage produced in Gem County, Idaho, during 1937 and 1938 on the same areas, typical for (A) nearly pure stands of downy chess (*Bromus tectorum*); (B) mixed stands of downy chess and native perennial forages; and (C) nearly pure stands of native perennials. Comparatively the native perennials are much more reliable forage producers in years of unfavorable precipitation.

greater difficulties than stockmen can be expected repeatedly to overcome. On the other hand, the area that bore mostly perennials produced 57% as much in the unfavorable year (1.534) as in the favorable one (2.7045), a reduction in forage which, though drastic, is

much nearer to the adjustment that stockmen might be able to make and still preserve economic stability.

The extreme variation in forage production from year to year and from one spot to another in the county points out specifically that where the vegetation consists largely of annual plants it is extremely difficult to make a grazing plan that is applicable beyond the current year. On the other hand, where the vegetation consists largely of perennial plants and of a sort good for forage, the data here presented show that the yields to be expected in unfavorable years are much higher and the variations from spot to spot and from year to year are very greatly reduced on a percentage basis. The difference in forage production by perennials between a season with a low precipitation and another season with a precipitation more favorable is great but does not even approximate the relative magnitude of differences shown during the same years and on similar sites by annual plants. Moreover, these grass annuals require moisture during a short period of a few weeks in the fall when they begin growth and again in the spring when they must grow rapidly if they are to make a good volume of forage during the season. Precipitation which comes after this period has passed is almost entirely lacking in effectiveness for annuals, whereas with perennials, many of which can grow whenever moisture is available, late moisture, though less effective than early, is still of considerable value. In 1937 moisture was very scarce or almost lacking during the period when downy chess makes its vegetative growth. Because of this, the survey of 1937 shows an extremely low production, and that of 1938 when the moisture was favorable both in amount and distribution, shows the large increases already described.

DATA FROM BOISE NATIONAL FOREST

Data that are highly corroborative of the conclusions in Gem County are presented in Table 4 and Fig. 3 in which are given the number of plants and the density of cover for a tract of similar range on the Arrowrock addition of the Boise National Forest in Idaho, about 60 miles southeast of Gem County. Dense stands of downy

TABLE 4.—*Number of plants and density of cover of downy chess in 1930 or 1931 and in 1936 or 1937 as indicated, Arrowrock addition of Boise National Forest.*

Area	1930 or 1931		1936 or 1937		Density 1931×1936 or 1937
	No. of plants	Density	No. of plants	Density	
Cow Creek*...	1,324	0.067	635	0.003	22.3×
Arrowrock					More than
Plot No. 1†	2,350	0.102	6	Trace	200×
Plot No. 10‡	1,108	0.098	2	Trace	200×

*Data for 1931 and 1937.
†Data for 1930 and 1936.
‡Data for 1931 and 1936.

ones. In 1938 the downy chess was just beginning to recover from the smut epidemic, which constitutes still another means of making forage production uncertain and thereby increasing the difficulty of making the required adjustments in livestock numbers on ranges producing principally downy chess.

Though actual figures for other localities are not available to establish the intensity of fluctuations in forage production from year to year, the variations throughout the Intermountain region are of about the same magnitude as those shown in Gem County. For example, in western Utah, during the extremely unfavorable year of 1934, the forage production of Russian thistle, where this was the predominating species, was only 12% of normal, whereas in 1936 it was nearly 15 times as great, or approximately 180% of normal, so far as normal could be established from the incomplete data available.

SUMMARY

Downy chess (*Bromus tectorum*), beginning about 1900, spread over the Intermountain region, occupying bare and nearly bare areas where the natural plant cover had either been broken or was greatly deteriorated. This plant normally begins growth in autumn when it forms winter tufts from which seed stalks grow rapidly as soon as warm weather comes the following spring. If dry fall weather delays germination till spring, the volume of growth is much smaller. When a dry fall is succeeded by a cold spring, or by a dry one, vegetative growth is extremely dwarfed, as occurred in 1937 in Gem County, Idaho. When moisture is abundant in both fall and spring, growth is vigorous as in 1938.

Downy chess is an important range plant especially on spring ranges because it is widespread and frequently occurs almost to the exclusion of perennial plants. Its high inflammability when dry makes the occurrence of grass fires frequent and these tend to eliminate most of the perennial plants that are still left, but does not injure downy chess. This plant is soft and fresh only during 4 to 6 weeks of spring and much less palatable for cattle and sheep during the remainder of the year, though new fall growth is readily eaten. The old stems are also consumed to some extent in fall and winter when they are soaked by wet snow or prolonged rains. Horses can use at least part of the dry stems and seeds in summer.

In Gem County the 1938 forage production on areas of several thousand acres was from 40 to 400% greater than in 1937. Production also varied widely from one area to another, both on different soil types and within the same soil type, probably owing largely to variations in soil depth and soil moisture.

Forage production on small plats bearing nearly pure stands of downy chess was 5 to 12 times as great in 1938 as on the same plats in 1937. Forage production from mixed stands of perennial plants and downy chess varied much less, and that from nearly straight stands of perennials still less. Remnant stands of perennial forages in moist years yielded approximately twice as much forage as did downy chess, and in years with a dry fall and a dry spring (1937) about 12 times as

much. A smut epidemic on downy chess also reduced its production on the Arrowrock addition to the Boise Forest almost to nothing for the 3 years of 1936–38.

These acute shortages in the yield of downy chess, which may come almost without warning, introduce such a large element of uncertainty into the feed supply program of stockmen that it is extremely hazardous for them to use this plant as a basis on which to establish perennial grazing operations.

SURFACE STERILIZATION OF NODULES WITH CALCIUM HYPOCHLORITE[1]

J. K. WILSON AND T. PUNYASINGHA[2]

NODULES on the roots of leguminous plants growing in the soil are exposed to the organisms therein. Decomposing organic matter, as well as that which may come from the nodule into the surrounding soil solution, provides a favorable environment for the development of the native flora. The intimate contact of the nodule with the soil solution in which the organisms develop makes it possible for the comparatively rough surface of the nodule to become impregnated with whatever organisms may be present. From descriptions of the manner in which the root nodule bacteria enter the root hairs and from the histological appearance of the nodule, as well as from its method of development, one might consider that the cells of healthy looking nodules which are below the cortax, and filled with bacteria, may be free from organisms other than the Rhizobium. A few authors have reported, however, that the Rhizobium is seldom a pure growth within the cells of the nodule, and one gets the impression from such reports that certain extraneous organisms are commonly found in the nodules along with the Rhizobium. A summary of such reports and finding is found in the studies of Fred, *et al.*[3] In concluding their remarks, they state that it is highly probable that faulty technic may account for some of the contaminants reported.

Various methods have been employed to remove the undesirable organisms from the surface of the nodules in order to obtain a pure culture of the organism from within the nodule. Some workers apparently prefer a certain method and obtain satisfactory results, while other workers experience difficulty with the method. The method proposed at this time has been followed since 1915.[4] It possesses unusual flexibility and efficiency, and by its use information was obtained concerning the occurrence of extraneous organisms within the nodule.

PROCEDURE

A germicide is probably of most service when it destroys the organisms on the surface of the nodules and does not penetrate in a reasonable period of time to the cells filled with the Rhizobium. It is still better if it soon loses its sterilizing power and leaves no toxic residue when only traces are left on the outer covering of the nodule. A germicide possessing these qualities is found in a solution of calcium hypochlorite.

Preparation of sterilizing solution.—The sterilizing agent is easily prepared, about 10 grams of fresh, dry, ordinary commercial chlorinated lime is triturated with 350 ml of water and filtered. This solution of calcium hypochlorite contains

[1]Contribution from the Department of Agronomy, Cornell University, Ithaca, N. Y. Received for publication August 31, 1939.

[2]Professor of Agronomy and Graduate Student, respectively.

[3]FRED, E. B., BALDWIN, I. L. and MCCOY, ELIZABETH. Root nodule bacteria and leguminous plants. Univ. Wis. Sci. Studies, 5:1–343. 1932.

[4]WILSON, J. K. Calcium hypochlorite as a seed sterilizer. Amer. Jour. Bot., 2:420–427. 1915.

about 5,000 ppm of active chlorine, a concentration that appears to be satisfactory for this kind of work. It can be stored fairly well in dark bottles under mineral oil.

Nodular material.—Healthy appearing plants are taken from the field and the roots washed in running water to remove most of the adhering particles of soil. The nodules may be removed by forceps, then placed in the solution of calcium hypochlorite where they remain for the desired time. Since the sterilizing agent soon disappears in the presence of organic matter, several hundred times as much solution of calcium hypochlorite as nodular material was used. This prevented a drastic reduction in the strength of the sterilizing agent. Any convenient container will serve as the sterilizing chamber.

Handling nodules and isolations.—After a nodule remains in the germicide for the desired time it is removed to sterile water for 4 or 5 minutes and then into sterile water in a petri dish. It is then crushed to liberate some of the organisms from the cells and handled in the usual manner for making isolations. The nodules can be transferred from the sterilizing solution to the surface of agar in test tubes and either left until the organism appears on the agar or until needed for crushing in the petri dish. By this procedure it is certain that active chlorine has disappeared. Undesirable organisms, if not destroyed, will usually show in the test tube, after a period of incubation. The medium employed contained peptone, salts, and saccharose. Such a medium appeared equally suitable for the rhizobia and for other organisms.

Observations were made of the platings for the rhizobia and for other organisms at intervals of 3 to 6 days, many stained preparations having been examined. In order to make certain that at least some of the colonies which appeared were the rhizobia, parts of many colonies were transferred to slopes and, subsequently, tested for their ability to effect nodulation. The method employed was that described by Wilson.[5]

RESULTS

A method that can be recommended with confidence, to destroy organisms on the surface of nodules when one wishes to obtain the rhizobia that is within the nodule should be applicable to material from many species. The method described above has been followed to destroy the organisms on the surface of nodules from more than 60 species of plants. More than 100 individual nodules have been employed from one species. In Table 1 is given information relative to the time nodules from four species should be immersed in the solution of calcium hypochlorite in order to obtain plates on which nearly all the colonies resemble those of the rhizobia. It is realized that the immersion can be longer for large nodules of certain species than for small nodules of others. This is important because the sterilizing agent should not be permitted to penetrate throughout the nodule. At the same time, the longer the action of the hypochlorite solution continues the greater is the chance of destroying the organisms on the surface or near the surface of the nodule.

Nodules of *Dalea alopecuroides* Willd. were immersed for 20 minutes. In the first plate where the nodule was crushed colonies resem-

[5]WILSON, J. K. Leguminous plants and their associated organisms. Cornell Univ. Agr. Exp. Sta. Mem. 221. 1939.

bling Rhizobium were found in four of the five cases. In the fifth case a mold appeared. In the second dilution only colonies resembling Rhizobium were seen on the five plates. Nodules of Dalea treated for 30 minutes gave similar results. When immersed for 40 minutes they gave many plates on which colonies resembling Rhizobium only were seen. Usually when two dilutions were made too many colonies were present in the plates. Occasionally, however, colonies of bacteria were observed which did not resemble those of the rhizobia. There was no uniformity in such occurrences. Sometimes they were on the plate in which the nodule was crushed, sometimes on the plate of the second dilution, and always appeared as surface colonies. Parts of eight colonies from nodules of Dalea immersed for 20 minutes, parts of four immersed for 30 minutes, and parts of two immersed for 40 minutes were transferred to slopes and without further examination for purity tested for their ability to effect symbiosis. These 14 transfers, each representing a nodule, were apparently pure cultures of rhizobia.

TABLE 1.—*Time of immersion of nodules for sterilization of surface and for obtaining growth of the Rhizobium on plates.*

Nodules from	Immersion time in minutes, probable success		
	Poor	Good	Injury
Dalea alopecuroides.............	10–15	20– 45	60 or longer
Glycine max....................	15–20	40–120	Longer than 120
Melilotus alba..................	5–10	15– 40	40 or longer
Trifolium repens................	5–10	15– 60	Longer than 60

Somewhat similar results were obtained when nodules of *Glycine max* (L.) Merr., *Melilotus alba* Desr., and *Trifolium repens* L. were immersed in the calcium hypochlorite solution, washed, crushed, and plated. Also there were 12 transfers, each representing a nodule of *Melilotus alba*. All but one effected symbiosis and this one was from a nodule immersed for 20 minutes. In addition, 22 transfers, each representing a nodule of *T. repens* were made. Of these seven were of nodules immersed for 10 minutes and five each of nodules immersed for 20, 30, and 40 minutes. Only two failed to effect symbiosis. One was from the 10-minute immersion and the other from the 20-minute immersion.

DISCUSSION AND CONCLUSION

A method for treating nodules of leguminous plants to destroy undesirable organisms on their surface has been presented. At the same time this treatment leaves the cells in the center of the nodules full of viable bacteria from which pure cultures of Rhizobium may be obtained. Traces of the hypochlorite solution adhering to the nodule when it is removed from the solution soon disappear and leave no toxic residue. The agent is cheap, efficient, convenient, possesses working latitude, and is easily prepared. When it is used a high percentage

of the colonies on the plates resemble those of Rhizobium. In many instances this is the only type of colony. When colonies develop that were easily identified as not Rhizobium they sometimes were in the petri dish where the nodule was crushed to literate the legume organisms and at other times in the second or third dilution. Their occurrence seemed to bear no relation to dilution or to the fragments of nodular tissue.

From the data presented it appears that the interiors of a vast majority of well-developed, clean, healthy-appearing nodules contain only the legume bacteria and that perhaps most organisms reported as contaminants within the nodule are the result of ineffective sterilization of the surface of the nodule. Organisms other than the Rhizobium that appeared on the platings of nodules after treatment and crushing developed mostly from material insufficiently exposed to the sterilizing agent. Nodules treated for sufficient time to permit considerable bleaching nearly always gave, on plating, colonies resembling those of Rhizobium. Transfers of such colonies when tested on seedlings usually effected symbiosis.

THE EFFECT OF CALCIUM ARSENATE UPON THE PRODUCTIVITY OF SEVERAL IMPORTANT SOILS OF THE COTTON BELT[1]

Clarence Dorman, Frederick H. Tucker, and Russell Coleman[2]

INVESTIGATIONS have indicated that accumulated arsenic in certain soil types has reduced their productivity. Morris and Swingle (6)[3] believed that the incorporation of arsenical compounds in the soil is dangerous practice and may cause considerable injury as the concentration of arsenic increases. Large amounts of arsenic have been found in some virgin soils but greater quantities occur in cultivated soils whose crops have been treated with arsenates for insect control. Many southern soils whose cotton crop is often dusted with calcium arsenate for boll weevil receive considerable quantities of arsenic; therefore, it is of economic importance to determine its effect upon the soil and its possibility of becoming a serious problem to agriculture.

Earlier workers have found that the effect of arsenic depends upon the nature of both soil type and crop. In South Carolina, Cooper, *et al.* (3) have shown that cotton grows normally on some soil types which have received 2,000 pounds of calcium arsenate, but its growth is greatly reduced on other soil types which have received only 50 pounds per acre. They have also reported that different crops vary in response. Rye, corn, sweet potatoes, and tobacco were very tolerant, but cowpeas, vetch, soybeans, cotton, and oats were very sensitive to arsenate applications. In Louisiana, Reed and Sturgis (7) found that cotton treated with calcium arsenate was not affected, but that rice following it was seriously injured.

Investigations have already revealed many interesting facts about the effect of calcium arsenate upon some soils, but more information is needed to determine the influence of arsenic on other soils of the cotton belt.

The purpose of this study was to investigate the effect of calcium arsenate upon the productivity of several important soils of the cotton belt and to determine its probable influence upon the future soil status.

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[1]Contribution from the Agronomy Department, Mississippi Agricultural Experiment Station, and the Division of Cotton Insect Investigations, Bureau of Entomology and Plant Quarantine, U. S. Dept. of Agriculture. Paper No. 14, New Series, March 23, 1939. Received for publication September 11, 1939.

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[3]Figures in parenthesis refer to "Literature Cited", p. 1028.

EXPERIMENTAL

SOILS

Seven important soil types, representing a large area of the cotton belt, were used in this study. The seven soils chosen were Cahaba fine sandy loam, Houston clay loam, Memphis silt loam, Norfolk sandy loam, Ruston fine sandy loam, Orangeburg fine sandy loam, and Sarpy fine sandy loam.

Cahaba fine sandy loam is a soil of the stream terraces in the Atlantic and Gulf Coastal Plain. The surface soil is gray, loose, friable, sandy loam; the subsoil is friable, reddish, sandy clay.

Houston clay loam is a well-drained soil of the Blackland Prairies occurring chiefly in Texas, Mississippi, and Alabama. The surface soil is black or nearly black clay loam; the subsoil is generally grayish-yellow or yellow clay; the substratum consists of marl or chalk.

Memphis silt loam is a well-drained soil developed from loess occurring on the bluffs on both sides of the Mississippi River southward from the vicinity of St. Louis almost to the Gulf of Mexico.

Norfolk sandy loam is a soil of the Atlantic and Gulf Coastal Plain of wide distribution and great agricultural importance. The surface soil is gray or light gray sandy loam; the subsoil consists of yellow, friable, sandy clay.

Orangeburg fine sandy loam occurs in the Atlantic and Gulf Coastal Plain in association with the Norfolk and Ruston soils. The surface soil is generally grayish-brown fine sandy loam; the subsoil is red, friable, sandy clay; and the substratum material is loose sand or fine sand.

Ruston fine sandy loam is a well-drained soil of the Atlantic and Gulf Coastal Plain with a surface soil of grayish-brown fine sand underlain by reddish-brown friable sandy clay subsoils with substratum of unconsolidated coastal plain materials. It is one of the most widely distributed soils of the coastal plain region. It has been leached of its bases and is generally medium or strongly acid throughout.

Sarpy fine sandy loam occurs in the first bottoms of the Mississippi River. It is a generally fertile soil composed of recent alluvium and ranks with the best cotton soils of the Mississippi delta region.

The seven soils vary greatly in texture, structure, reaction, and organic matter and should be representative of the most important soils in the eastern section of the cotton belt. Thirty inches of each soil type were removed in their relative position to seven 3 x 16 feet concrete plots, where each received different treatments of calcium arsenate.

TREATMENTS

Each soil type, located in seven different concrete plots, was given the following treatments: 0, 50, 100, 200, 400, 800, and 1,600 pounds of calcium arsenate per acre which was broadcast on the soil and mixed to a depth of 4 or 5 inches with shovels and hoes. Applications of calcium arsenate were made in the spring of 1935, a few days before the summer crops of cotton, corn, and soybeans were planted. Eight hundred pounds per acre of 4–8–4 fertilizer was applied to all plots each year. Each plot was replicated three times.

PROCEDURE

Germination and seedling counts were made upon cotton, corn, and soybeans. Then in the fall hairy vetch, Austrian peas, and oats, three important winter

cover crops, were planted on the seven plots of each soil type. Yields of all winter crops were obtained in 1935 and 1936 in order to measure the effect of the arsenicals on production. About 10 soil samples were taken from the top soil of each plot and after these were mixed into one composite sample, chemical and mechanical analyses and pH determinations were made.

RESULTS AND DISCUSSION

EFFECT OF CALCIUM ARSENATE UPON GERMINATION AND SEEDLINGS

An examination of Table 1 shows that neither germination nor seedlings of cotton on any soil type were affected by the 50-, 100-, or 200-pound arsenate application, and only the seedlings on Norfolk and Cahaba sandy loams were affected by the 400-pound treatment. When 800-pound applications were made, both germination and seedlings were greatly injured upon most of the soils, and when 1,600 pounds of arsenate were applied germination and viability were greatly reduced on all soil types except Houston clay loam. The living seedlings on Cahaba sandy loam were reduced from 77% to 5% by the 1,600-pound treatment. Although germination seems to be arrested by the heavier arsenate applications, the greatest toxicity occurs in the seedling stage, and the extent of this effect depends upon the nature of the soil.

The results with corn show that germination was not affected by calcium arsenate on any soil type and the seedlings were not affected by the lighter applications; however they were injured by the 800-pound and 1,600-pound applications, especially on the sandy soils. The viability of seedlings on Cahaba sandy loam was reduced from 90% to 10% by the 1,600-pound application.

Germination studies with soybeans show that its seed were only sensitive to heavy applications of calcium arsenate. The 800- and 1,600-pound applications reduced the percentage of germination in almost every soil, the germination of seed planted on Cahaba soil being reduced from 68% to 5%.

The effect of calcium arsenate upon germination and seedlings depends upon the nature of the plant as well as the soil. Neither germination nor seedlings of any plant were affected by the 50-, 100-, or 200-pound application, the larger of these applications being more calcium arsenate than most soils receive over a period of several years. The germination of cotton and soybean seed was greatly injured by the heavy arsenate treatments, but the germination of corn seed was not affected by any calcium arsenate treatment. The viability of cotton and corn seedlings was greatly reduced by the heavy arsenate applications; however, the injury varied with soil type. The seedlings on light, sandy soils were injured much more than those on heavy, clay soils. These results suggest that the harmful effect of calcium arsenate upon crops grown on light, sandy soils is because of the injury received in the seedling stage. Since plants are usually treated with calcium arsenate after their seedling stage, the possibility of injury at this stage is eliminated.

TABLE 1.—*Effect of calcium arsenate upon germination and seedlings.*

Soil type	Germination or seedlings	Percentages with applications of calcium arsenate in pounds per acre of						
		0	50	100	200	400	800	1,600
	Effect upon Cotton*							
Ruston fine sandy loam....	Germination	78	74	75	81	71	56	53
	Seedlings	72	69	70	72	62	35	23
Cahaba fine sandy loam....	Germination	78	80	65	83	67	61	44
	Seedlings	77	75	61	80	53	34	5
Norfolk sandy loam.......	Germination	66	78	65	66	56	50	18
	Seedlings	55	71	54	55	25	12	4
Orangeburg fine sandy loam	Germination	75	69	68	66	68	64	51
	Seedlings	71	66	59	58	62	57	39
Memphis silt loam........	Germination	75	77	76	80	68	77	52
	Seedlings	70	71	72	75	62	67	33
Houston clay loam........	Seedlings	46	55	51	56	46	50	56
	Effect upon Corn							
Ruston fine sandy loam....	Germination	87	87	93	93	93	97	90
	Seedlings	87	87	93	93	83	73	53
Cahaba fine sandy loam....	Germination	90	97	90	83	97	90	97
	Seedlings	90	93	90	73	73	53	10
Norfolk sandy loam.......	Germination	97	90	87	87	93	90	93
	Seedlings	97	83	83	87	77	60	40
Orangeburg fine sandy loam	Germination	100	87	100	90	87	87	83
	Seedlings	97	87	100	90	83	70	63
Memphis silt loam........	Germination	93	93	83	93	77	100	97
	Seedlings	90	93	83	90	73	93	87
Houston clay loam........	Seedlings	93	87	87	87	93	50	77
	Effect upon Soybeans†							
Ruston fine sandy loam....	Germination	72	68	69	60	49	27	16
Cahaba fine sandy loam....	Germination	68	85	87	65	40	11	5
Norfolk sandy loam.......	Germination	73	68	73	71	67	56	37
Orangeburg fine sandy loam	Germination	60	33	39	41	40	39	41
Memphis silt loam........	Germination	77	67	69	64	73	27	13
Houston clay loam........	Germination	73	72	71	72	73	72	60

*Results are not reported on Sarpy fine sandy loam because seed on this soil were replanted. Only seedling counts were made on Houston clay loam.
†Seedling counts were not made on soybeans.

EFFECT OF CALCIUM ARSENATE UPON THE YIELD OF OATS, AUSTRIAN PEAS, AND VETCH

The data in Table 2 show that the yield of oats was not affected by the 50-, 100-, or 200-pound treatments, but that it was greatly reduced by the heavy applications of calcium arsenate. In 1935, soon after the arsenate was applied, yields on all soil types were affected by the 400-, 800-, and 1,600-pound applications, and there were 13 crop failures on these plots. In 1936, the yields on most soil types were still affected, but not nearly as much as in 1935. There was only one crop failure in the heavily treated plots. Oats grown on the sandy soils, Norfolk, Cahaba, Orangeburg, and Ruston, was more easily affected than that grown on Houston clay loam. However, both sandy

and clay soils were able to recuperate quickly from the toxic effect of calcium arsenate. In 1935, the 400-pound treatment reduced the

TABLE 2.—*Effect of calcium arsenate upon the yield of cover crops.*

Soil type	Year planted	Application of calcium arsenate in pounds per acre						
		0	50	100	200	400	800	1,600
		Yield of Oats, Lbs. Green Weight per Acre*						
Ruston fine sandy loam	1935	1,450	1,180	2,360	816	363	0	0
	1936	2,720	1,542	2,178	2,540	2,360	1,905	1,360
Cahaba fine sandy loam	1935	3,660	2,450	2,630	1,630	0	0	0
	1936	1,724	2,902	1,542	1,088	998	454	0
Norfolk sandy loam...	1935	2,990	3,900	2,270	454	181	0	0
	1936	2,430	2,810	1,815	2,360	2,270	—	635
Orangeburg fine sandy loam..............	1935	3,075	2,990	1,630	273	91	0	0
	1936	2,720	2,540	1,905	3,265	2,270	2,450	998
Houston clay loam....	1935	2,363	2,182	2,720	2,900	1,453	1,815	0
	1936	908	998	1,360	1,540	1,180	1,450	1,360
Sarpy fine sandy loam..	1935	454	540	726	454	0	0	0
	1936	818	1,180	1,180	908	546	546	272
		Yield of Austrian Peas, Lbs. Green Weight per Acre						
Ruston fine sandy loam	1935	6,710	9,150	7,260	4,350	3,270	1,360	181
	1936	4,355	2,270	2,810	4,900	5,080	3,538	2,270
Cahaba fine sandy loam	1935	10,800	6,710	3,260	6,160	3,180	0	0
	1936	3,900	4,720	3,630	4,080	3,900	1,815	0
Norfolk sandy loam...	1935	4,810	6,260	5,340	3,540	1,450	816	0
	1936	5,355	3,630	6,540	6,990	3,810	1,815	1,179
Orangeburg fine sandy loam..............	1935	8,180	7,980	10,400	8,890	12,250	3,810	2,720
	1936	3,540	4,355	2,902	3,082	2,270	2,902	1,230
Memphis silt loam....	1935	2,450	2,360	2,540	2,990	4,450	3,450	1,450
	1936	4,353	3,448	2,724	2,540	2,992	2,720	2,086
Houston clay loam....	1935	7,080	9,255	10,165	8,510	8,510	8,620	3,900
	1936	1,905	2,810	2,360	3,900	4,080	2,360	2,178
Sarpy fine sandy loam..	1935	10,708	12,600	10,600	8,440	3,260	908	0
	1936	8,620	10,160	8,345	12,975	2,630	3,084	635
		Yield of Hairy Vetch, Lbs. Green Weight per Acre						
Ruston fine sandy loam	1935	3,810	5,540	5,460	3,900	2,540	1,725	0
	1936	4,355	3,990	4,540	4,990	3,900	2,810	635
Cahaba fine sandy loam	1935	4,075	3,450	3,080	2,720	1,900	1,810	0
	1936	2,270	3,080	1,905	3,540	2,810	1,815	0
Norfolk sandy loam...	1935	6,800	7,520	9,530	2,260	544	0	0
	1936	2,630	3,450	2,540	3,355	2,410	1,088	0
Orangeburg fine sandy loam..............	1935	5,440	8,340	10,400	6,160	8,620	5,800	1,815
	1936	4,355	2,720	2,720	4,355	3,448	5,172	1,270
Memphis silt loam....	1935	2,720	2,540	2,720	1,810	3,260	1,540	454
	1936	4,355	4,080	2,992	4,170	3,720	2,720	1,815
Houston clay loam....	1935	6,540	10,400	9,255	8,350	4,710	5,620	908
	1936	1,995	2,080	2,810	2,360	2,088	2,720	1,088
Sarpy fine sandy loam..	1935	7,260	8,340	9,800	9,350	2,720	1,450	0
	1936	3,265	5,355	4,170	2,270	5,355	2,300	908

*Results are not given for Memphis silt loam because cattle damaged the crop in 1935.

yield of oats on Norfolk sandy loam from 2,990 to 181 pounds per acre; whereas, in 1936, it only reduced the yield from 2,430 to 2,270 pounds of green weight per acre. These data show that the toxic effect of arsenic is much greater immediately after the heavier applications are made and indicate that large amounts of soluble arsenic are lost, either by leaching or fixation, after a year.

The yield of Austrian peas was also reduced by the heavier arsenate treatments, but not as much as the yield of oats. In 1935, the Austrian peas on Ruston and Norfolk were injured by the 200-pound applications and those on Cahaba and Sarpy by the 400-pound application, but the yields on Orangeburg, Memphis, and Houston were not affected until 800- and 1,600-pound treatments were made. In 1936 hardly any yields were affected by arsenates, except on the 800- and 1,600-pound treated plots. These data also show that much of the toxic effect is lost one year after the arsenate was applied.

The yield of hairy vetch was also affected by the heavy treatments of calcium arsenate and the effect was very similar to that obtained with Austrian peas. In 1935, only the vetch on Norfolk and Cahaba sandy loams was affected by the 200-pound treatments, but yields on all other soils were affected by either the 400-, 800-, or 1,600-pound treatments. However, in 1936, the harmful effect was much less in every case. Even vetch on Norfolk and Cahaba soil was not affected except on the 400-, 800-, and 1,600-pound treated plots.

The data above indicate that both soil and crop determine the effect of applied arsenic. Of the cover crops studied, oats seems to be much more sensitive to arsenic than hairy vetch or Austrian peas. The light sandy soils, Ruston, Norfolk, Cahaba, and Sarpy, were more affected than the heavier Houston and Memphis soils. In most cases 400 pounds or more calcium arsenate were required to reduce materially the yield of oats, vetch, or peas. Although the yields on some soils were reduced by 200 and 400 pounds of arsenate in 1935, only those on the 800- and 1,600-pound plots were seriously affected in 1936. Both sandy and clay soils were able to dispose of large amounts of toxic arsenic over a period of one year. This indicates that even the most liberal application of calcium arsenate to cotton for insect control on the soils studied will not be great enough to affect a following crop of hairy vetch, oats, or Austrian peas.

EFFECT OF TIME UPON THE TOXICITY OF CALCIUM ARSENATE IN THE SOIL

Soil samples were taken from each plot soon after the calcium arsenate was applied in 1935 and similar samples were obtained one year later. Both were analyzed for water-soluble arsenic and the results are reported in Table 3. These data show that there was no great increase in the amount of water-soluble arsenic until 400 pounds of calcium arsenate per acre had been applied. Analyses from the 400-pound treated plots indicate that arsenic accumulates much faster in sandy than in clay soils, showing 40 ppm in Cahaba sandy loam, 60 ppm in Ruston and Orangeburg fine sandy loams, and only 9 ppm in Houston clay loam. These data suggest that the properties of Houston clay loam fix the arsenic into an insoluble state, whereas

those of Cahaba are unable to fix as much arsenic. One year later analyses from the same plots show that water-soluble arsenic in Cahaba sandy loam has been reduced from 40 to 16 ppm, while that in Houston clay loam has only been reduced from 9 to 8 ppm. The results show that great quantities of arsenic were lost from the sandy Cahaba with time, but very little was lost from the clay soil because it was probably held in an insoluble state. Analyses in 1935 from the 800-pound and 1,600-pound treated plots showed that great quantities of arsenic had accumulated in every soil. Even the water-soluble arsenic in Houston clay loam had increased to 200 ppm when 800 pounds of calcium arsenate were applied. The fixing capacity of the soil was probably saturated at some point between 400 and 800 pounds per acre, after which the rest of the applied arsenic remained water soluble.

TABLE 3.—*Parts per million of water-soluble arsenic in soils in 1935 and 1936.*

Soil type	Year	Application of calcium arsenate in pounds per acre						
		0	50	100	200	400	800	1,600
Ruston fine sandy loam	1935	2	5	9	8	60	190	450
	1936	Trace	2	2	4	8	14	250
Cahaba fine sandy loam	1935	Trace	4	4	11	40	120	300
	1936	Trace	2	4	4	16	80	87
Norfolk sandy loam	1935	Trace	2	2	14	30	80	400
	1936	Trace	Trace	2	6	16	24	60
Orangeburg fine sandy loam	1935	Trace	1	Trace	2	60	120	300
	1936	Trace	Trace	Trace	2	4	30	150
Memphis silt loam	1935	Trace	2	2	4	11	120	300
	1936	Trace	Trace	2	1	5	28	175
Houston clay loam	1935	Trace	2	4	7	9	200	270
	1936	Trace	2	4	4	8	80	100
Sarpy fine sandy loam	1935	1	8	12	30	100	275	500
	1936	Trace	4	4	5	40	80	100

In every case the water-soluble arsenic was much less in 1936 than in 1935 and only in the 800- and 1,600-pound plots was there enough arsenic remaining to cause serious injury to plants. These data substantiate those obtained with crop yields, which show that only those grown on the 800- and 1,600-pound treated plots were greatly affected in 1936.

The above results prove conclusively that great quantities of water-soluble arsenic are lost from the soil either by leaching or fixation. More of the applied arsenic accumulated immediately in the light than in the heavy textured soils, but more was also lost from the light soil during one year's time. This indicates that the arsenic applied to clay soils is lost immmediately, but that that applied to sandy soils is lost gradually. Since harmful quantities of arsenic did not accumulate until 400 pounds of calcium arsenate had been applied, and since most of this was lost in one year, it is doubtful that the present rate of dusting cotton will ever cause enough accumulation to be injurious to crops.

EFFECT OF PROPERTIES OF THE SOIL UPON ITS RESPONSE TO CALCIUM ARSENATE

In order to determine some reason for different effects of calcium arsenate upon various soils, chemical and mechanical analyses of each soil were made before calcium arsenate was applied. Determinations of total CaO, Fe_2O_3, Al_2O_3, MgO, P_2O_5, SiO_2, and clay content are shown in Table 4. Cahaba, Norfolk, and Ruston sandy loams —the soils most affected by calcium arsenate—were lower in iron, aluminum, calcium, and magnesium, those elements which have been thought to fix arsenic. The clay content was also much lower in these soils. Houston clay loam, the soil least affected by calcium arsenate, contained the highest amount of these elements. There is a high correlation between the presence of these elements and the effect of calcium arsenate upon the productivity of the soils. These results are in agreement with those obtained by other investigators. Zuccari (8) found that fixation of arsenic varied directly with the amount of iron in the soil, and he attributed a minor fixing power to aluminum and to calcium and magnesium carbonates. The authors have previously (4) concluded that arsenic fixation is principally due to the colloidal material, which contains a high iron content.

TABLE 4.—*Important physical and chemical characteristics of soils.*

Soil type	CaO %	Fe_2O_3 %	Al_2O_3 %	MgO %	P_2O_5 %	SiO_2 %	Clay* %	pH† %
Ruston fine sandy loam	0.20	1.35	5.79	0.25	0.063	91.25	8.4	5.58
Cahaba fine sandy loam	0.15	0.91	3.01	0.15	0.040	91.90	6.4	5.10
Norfolk sandy loam	0.19	1.29	4.73	0.18	0.076	93.55	10.4	4.79
Orangeburg fine sandy loam	0.28	2.39	9.44	0.34	0.066	84.77	26.8	5.44
Memphis silt loam	0.35	2.62	10.27	0.54	0.107	78.90	27.2	5.59
Houston clay loam	1.53	4.22	18.22	0.80	0.155	62.02	48.0	6.94
Sarpy fine sandy loam	1.00	2.62	11.07	0.60	0.209	76.85	24.0	6.02

*Determined by Boyoucos method (2).
†Determined by potentiometer method.

Therefore, it appears that the presence of a large amount of iron, aluminum, calcium, magnesium, and clay offset the toxic effect of arsenic, and those soils which are deficient in these elements will probably be most affected by heavy calcium arsenate treatments.

SUMMARY

Seven important soil types, representative of many soils in the cotton belt, were removed to concrete plots and treated with varying amounts of calcium arsenate. Different investigations were conducted on these soils, and the following conclusions drawn:

1. Neither germination nor seedlings were injured on any soil until 400 pounds per acre or more of calcium arsenate were applied. The greatest injury from the heavier applications occurred in the seedling stage and the extent of this injury depended upon the nature of the soil type. Cahaba, Norfolk, and Ruston sandy loams were more sensitive to arsenic than the other soils.

2. Crop yields from oats, Austrain peas, and hairy vetch planted immediately after the arsenic was applied and one year later show that yields were not affected except by heavy treatments and much of their toxicity was lost during one year's time. Oats seemed more sensitive to arsenic than Austrian peas and hairy vetch, but all crops grown on Norfolk, Ruston, and Cahaba sandy loams were injured more than those grown on heavier soils.

3. Large amounts of water-soluble arsenic did not accumulate in any soil until 400 pounds of calcium arsenate had been added, and then only in the sandy soils. Large quantities were lost from the heavily treated soils in one year's time.

4. Those soils which were most sensitive to arsenates (Norfolk, Cahaba, and Ruston sandy loam) contained the smallest amount of clay, iron, aluminum, calcium, and magnesium. Houston clay loam, the soil least affected by calcium arsenate, contained the largest quantity of these constituents.

5. Since hardly any damage to germination, seedlings, or crop yields occurred until an application of 400 pounds of calcium arsenate was made, and since large quantities of toxic arsenic were lost with time, the average application of calcium arsenate for insect control will probably never cause enough accumulation to injure crops usually grown on the soils used in this study.

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STRAIN TESTS OF RED AND WHITE CLOVERS[1]

O. S. Aamodt, J. H. Torrie, and O. F. Smith[2]

THE use of adapted strains is essential for success with red and white clovers. This has been reported often with red clover but not for white clover. Frequently a shortage of domestic red clover seed in the United States results in large importations of unadapted foreign seed. Such a situation arose immediately following the World War and again in 1924, 1926, 1927, and 1937.

Numerous tests conducted at various experiment stations have shown, with few exceptions, that foreign strains of red clover are decidedly inferior to domestic strains. Among the earlier work was that of Moore (4),[3] which showed that European red clovers were not sufficiently hardy for Wisconsin conditions. During the years 1922 to 1929 tests were conducted at several experiment stations in cooperation with the U. S. Dept. of Agriculture. The results of these tests, which are reported by Pieters and Morgan (6), show that foreign red clovers, with few exceptions, are unadapted for the north central and eastern United States. A more detailed report of these studies at Wisconsin, New York, and Kentucky are given respectively by Delwiche (2), Wiggans (7), and Fergus (3). Their conclusions are essentially the same as given by Pieters and Morgan (6). From the results of tests of foreign red clovers in Illinois over a 15-year period Pieper and Burlison (5) state "the foreign seeds germinated well, but the stands though good the first year, were soon lost because of winter-killing and susceptibility to disease and insect injury. The true inferiority of the foreign strains, except those from Canada, showed up in their inability to produce a crop the second year".

Interest was renewed in this subject in 1937 as a result of large importations of foreign red clover seed, caused by a shortage of domestic seed. Aamodt, Delwiche, and Stone (1) stress the disadvantage of using foreign seed. They state that in years when winter injury is negligible foreign red clovers may produce a fair yield in the first but the second cut is usually small. There is also the danger that domestic stocks will become contaminated by mechanical mixtures or cross pollination with foreign strains.

MATERIALS AND METHODS

In order to obtain more recent data on the relative performance of foreign and domestic clovers, under Wisconsin conditions, some 63 samples of red clover and 16 of white clover were planted in duplicate randomized plots in the spring of 1937 at the University Hill Farms. Similar plots of some 80 strains of red clover and

[1]Cooperative investigations of the Wisconsin Agricultural Experiment Station and the Division of Forage Crops and Diseases, U. S. Dept. of Agriculture. Paper No. 146 from the Department of Agronomy, University of Wisconsin, Madison, Wis. Published with approval of the Director of the Wisconsin Agricultural Experiment Station. Received for publication September 29, 1939.

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[3]Figures in parenthesis refer to "Literature Cited", p. 1037.

20 of white clover were planted in the spring of 1938. The samples from states other than Wisconsin were obtained from A. L. Stone of the Wisconsin State Seed Testing Laboratory, and E. A. Hollowell of the U. S. Dept. of Agriculture. The Wisconsin samples were secured from farmers. The size of the plots was 5 by 10 feet, or 1/870 of an acre. The seed was sown in the spring without a nurse crop at a rate of 20 pounds per acre. The heavy rate of seeding used was to assure a good stand on all plots. Favorable weather for germination of the seed and for the early growth of the clover followed. The growth of annual weeds was kept in check by several mowings above the tops of the red clover plants during the summer.

In order to secure additional information, under conditions similar to those found on the average farm, in 1938 representative strains of foreign and domestic clover were sown in strips approximately 400 feet long and 7 to 14 feet wide. The field was first sown with Wisconsin Pedigree 38 barley. The clover seed was then sown on the surface of the soil at a rate of 12 pounds per acre with a wheelbarrow seeder, followed with a cultipacker seeder with timothy, at the rate of 5 pounds per acre.

To obtain a measure of the relative survival of the different strains, counts were made of the number of plants per unit area during the fall and early spring. The method used was to count the plants enclosed within a 6 by 6 inch square thrown at random on the plot. Six counts, two each by three readers, were taken for each plot. Estimates on the percentage coverage were made independently by three readers. Yields were taken on the first and second cut during the 50% bloom stage. The yield of weeds was recorded separately for the second cut. Dry weight determinations were based on samples of 700 to 1,000 grams.

EXPERIMENTAL RESULTS

RED CLOVER, 1937 PLANTING

The data in Table 1 give a summary by country of origin for the red clover samples planted in the spring of 1937. The number of plants is the total of six counts. For all the characters studied the difference between domestic and foreign strains were found to be highly significant.

The fall counts were taken on September 23, 1937, and the spring counts and percentage coverage on April 30, 1938, shortly after the start of spring growth. The date when each strain was approximately in the 50% bloom stage was recorded prior to the first cut in order to have some idea of the relative earliness of the strains. Yields were taken on the first cut during the period, June 10 to 30, and the second cut, August 4 to 15.

The data in Table 1 show that the number of plants for six counts both fall and spring, percentage coverage, and yield of hay for both first and second cuts were much lower for the European than for the domestic strains. The yield of weeds, however, is much higher for the European strains. The reduction in yield of the European strains is almost entirely the result of their inability to survive during the first year of growth. This probably was due to hot dry weather resulting in a heavy mortality of the plants weakened by leafhoppers. The differential summer-killing of foreign and domestic strains is shown in Fig. 1. This failure to survive the year of seeding probably has not been fully appreciated in the past and may have been reported as failure to survive the winters.

TABLE 1.—*Summary of data by country of origin for domestic and foreign red clover strains planted in the spring of 1937 at the University Hill Farms, Madison, Wisconsin*

Country	Number of samples	Total plants for six counts: FALL 1937		Total plants for six counts: SPRING 1938		Coverage, spring 1938		50% bloom	YIELD OF DRY HAY: First cut		YIELD OF DRY HAY: Second cut		YIELD OF DRY HAY: Total		YIELD OF DRY WEEDS Second cut	
		Number	% U. S. av.	Number	% U. S. av.	%	% U. S. av.		Tons per acre	% U. S. av.	Tons per acre	% U. S. av.	Tons per acre	% U. S. av.	Tons per acre	% U. S. av.
United States:																
Wisconsin	17	35	92	28	97	66	99	June 8	2.22	100	1.13	104	3.35	101	0.18	78
Other states	12	42	111	29	100	68	101	June 9	2.24	100	1.03	94	3.27	98	0.31	135
Average	29	38	100	29	100	67	100	June 9	2.23	100	1.09	100	3.32	100	0.23	100
Canada	7	39	103	33	114	72	107	June 22	2.64	118	0.91	83	3.55	107	0.40	174
Europe:																
France	1	16	42	5	17	5	7	June 9	0.51	23	0.17	16	0.68	20	0.60	361
Roumania	2	14	37	12	41	20	30	June 13	0.76	34	0.50	46	1.26	38	0.73	317
Czechoslovakia	1	13	34	11	38	15	22	June 15	0.87	39	0.27	25	1.14	34	0.64	279
Latvia	1	13	34	6	21	7	10	June 14	0.54	24	0.31	28	0.85	26	0.61	265
Wales	1	18	47	10	34	18	27	July 7	1.42	64	0.49	45	1.91	58	0.70	304
Hungary	8	15	39	11	38	15	22	June 13	0.74	33	0.29	27	1.03	31	0.83	361
Poland	9	10	26	8	28	9	13	June 14	0.57	26	0.20	18	0.77	23	0.89	387
Average	23	13	34	9	31	13	19	June 15	0.69	31	0.27	25	0.96	29	0.81	352
Chile	1	36	95	20	69	31	46	June 12	1.22	55	0.57	52	1.79	54	0.56	243
New Zealand	3	38	100	26	90	62	67	June 21	1.69	76	0.73	65	2.42	73	0.37	161

The average spring survival of the domestic and foreign red clovers was 75 and 69%, respectively, of their fall stand. This shows that although the winter of 1937–38 was not severe, some winter-killing occurred. In this respect the difference between domestic and European red clovers is not statistically significant.

The average yield of dry hay for the European strains for the first and second cut was 31 and 25%, respectively, of that produced by the domestic strains. This shows that although the yield of the European strains was much less than that of the domestic strains, the ratio between the two was similar for both cuts. The difference between the first and second cutting of European strains, when compared with domestic, is smaller than that commonly reported, probably because of the very favorable growth conditions throughout the 1938 season. The domestic strains were taller and flowered earlier and more profusely than the European strains. Several of the Canadian strains were of a semi-mammoth type and consequently bloomed later.

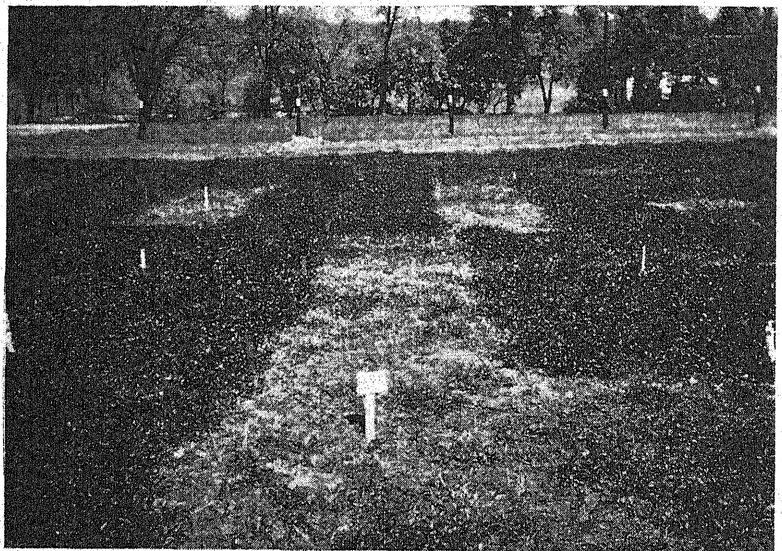

FIG. 1.—Differential summer-killing of foreign and domestic red clover strains during the first year's growth, summer of 1937. Plots with poor growth foreign strains, good growth domestic strains.

A strain from Chile had a fall and spring stand of 95 and 69%, respectively, of the average of the domestic strains. The total yield for both cuts was 54% of the domestic average. On the basis of this one strain from Chile the data indicate that red clovers from Chile are not adapted to Wisconsin conditions.

The domestic strains showed a greater vigor of growth. The average spring stand of the European strains was 31% of the average of the domestic strains, while the percentage coverage was only 19. Since the spring stand of the European strains was only 31% of the average

of the domestic strains, other things being equal, it would be reasonable to assume that the average yield of the foreign strains would be greater than 31% of the average of the domestic strains; for it is to be expected that the yield would not be directly proportional to the stand. This is indicated by the results obtained from four of the Wisconsin plots which had a relatively poor stand.

The average spring stand and percentage coverage of these four Wisconsin strains was 52 and 65, respectively, of the average of all of the United States strains, while the average yield of the first and second cuts was 86 and 85%, respectively, of the average of all the United States strains. One strain from Hungary, which was the best of the European strains, had a spring stand of 86%, spring coverage of 85%, and yield of first cut of 66% and yield of second cut of 50% of the United States average. This indicates that the yield of the Wisconsin strains with a poor spring stand was higher than would be expected if the yield was directly proportional to the stand, whereas, for the European strains, on the average, the yield was proportional to the stand.

Considerable interest is being shown throughout the country in long-lived, one-cut or mammoth types as compared to the medium or two-cut types. Several mammoth strains were included in the 1937 tests, consisting of Graham's Mammoth and five strains from Canada. Graham's Mammoth has been developed during the past 40 years by P. S. Graham, a farmer at Fennimore, Wisconsin. The 50% bloom stage for the mammoth types was approximately two weeks later than for the medium types. Graham's Mammoth yielded 122, 98, and 114%, respectively, of the average of all domestic strains for the first, second, and combined cuts. The corresponding percentages for the average of the Canadian mammoth strains were 131, 85, and 116. These results indicate that in a season favorable for two cuts from mammoth clovers, the mammoth types will produce as large a yield as the medium types. When mammoth types are left to the 50% or full bloom stage of development before cutting as is the practice with the medium red clovers, a coarse stemmy hay is likely. If the mammoth is cut in the early bloom stage, which is usually about one week after the medium clover, a quality of hay equal to the mediums can be produced. In addition, considerably more growth is available for late summer or early fall and under certain conditions into the third or fourth years.

RED CLOVER, 1938 PLANTING

The year 1938 was an ideal clover year for domestic strains. The foreign red clovers, however, suffered severely from leafhopper damage during midsummer. The difference in the vigor of growth of the foreign and domestic strains was very noticeable at this time. September was very wet and cool which aided in eliminating the leafhoppers and allowed the foreign red clovers to recover from earlier damage by the leafhoppers. Counts made in the fall of 1938 on the 5 by 10 feet observation plots showed no significant difference in the relative stand of foreign and domestic strains. The percentage coverage and vigor of growth were estimated on October 28. The index for

vigor of growth was based on a scale of 1 (very weak growth) to 10 (very vigorous growth). The average percentage coverage and index of vigor of the foreign strains were 80 and 75%, respectively, of the average of the domestic strains. In the spring of 1939 the stand of all strains was very poor due to winter-killing.

The strains planted on the strips 400 feet long and 7 to 14 feet wide, survived the winter much better. The stand of all strains, with the exception of Graham's Mammoth, on approximately two-thirds of the field was very poor as a result of a heavy growth of volunteer barley in the fall of 1938. The good stand of Graham's Mammoth indicates that under the conditions of this experiment it has the ability to withstand adverse conditions much better than the medium red clovers tested.

The data given in Table 2 on the relative stand in the fall of 1938 and the spring of 1939, as well as the yield of dry hay, are for the portion of the field on which the stand was reasonably good. The stand counts, which were taken as described previously, except area, represent the number of plants found in 60 square feet. Five quadrats each 16 feet square were taken at random for all strains to give an estimate of the yield.

TABLE 2.—*Summary of data by strain for domestic and foreign red clovers planted in the spring of 1938 with a barley nurse crop at the University Hill Farms, Madison, Wisconsin.*

Strain	Plants per 60 square feet		Yield of dry hay, first cut, tons per acre		
	Fall, 1938	Spring, 1939	Clover	Timothy	Both
Wisconsin	130	75	0.95	0.66	1.61
Longhurst (Idaho)	147	42	0.66	1.05	1.71
Graham's Mammoth	151	156	1.86	0.37	2.23
New Zealand	120	3	0.10	1.63	1.73
Poland	109	16	0.30	1.10	1.40
Latvia	85	15	0.25	1.14	1.39
M. S. D.*	27	30	0.34	0.33	—

*M. S. D. Minimum difference between strains required to be significant at 5% level.

An analysis of the data shows that in the fall of 1938 the strain from Latvia was the only one which differed significantly in stand from the Wisconsin check. In the spring all three foreign strains and Longhurst's from Idaho had a significantly poorer stand than the Wisconsin check, while the stand of Graham's Mammoth was significantly better. Graham's Mammoth was the only strain which did not have a marked reduction in stand during the winter. The differences in stand are reflected by the large variation found between strains for yield of dry hay. The tonnage of dry clover hay produced by Graham's Mammoth was almost twice as great as that for the

Wisconsin check. The hay from the plots seeded to the foreign strains of clover consisted largely of timothy.

The authors made a trip through southwestern Wisconsin during the last week of June 1939. The only field of red clover and timothy visited which had a good stand of red clover was a field of mammoth red clover on the farm of P. S. Graham at Fennimore, Wisconsin. This observational evidence gives additional support to the experimental data, which indicates the superiority of Graham's Mammoth Clover over the medium clover type under adverse conditions.

WHITE CLOVER, 1937–38 PLANTINGS

The data on the percentage coverage of the white clover strains planted in conjunction with the 5 by 10 feet red clover plots are summarized in Table 3. The stand of all strains planted in the spring of 1937 was excellent in the spring and fall of 1938. Differential winter-killing, however, occurred during the winter of 1938–39. The percentage coverage of the strains from Poland, England, and New Zealand were very poor in comparison with those from Wisconsin, Sweden, and Denmark.

The strains planted in the spring of 1938 entered the winter in excellent condition. The strains from Louisiana and Mississippi were several inches taller and had a much more vigorous growth than the Wisconsin strains. The Louisiana and Mississippi strains, however, were killed out practically 100% by the winter of 1938–39. This difference in ability to survive the winter of 1938–39 is shown in Fig. 2.

FIG. 2.—Differential winter-killing of white clovers during the winter of 1938–39. Wisconsin strain, plants alive (left); Louisiana strain, plants dead and weeds abundant (right).

The spring stand of the foreign strains, for the most part, was considerably poorer than that of the Wisconsin strains.

Two strains of white clover from Louisiana and one from Wisconsin were planted with the 400-foot strips of red clover. The stand of all three strains was excellent in the fall of 1938. The following spring, however, the Louisiana strains were dead, while the Wisconsin strain showed excellent growth.

TABLE 3.—*Percentage coverage by state or country of origin of domestic and foreign white clover strains planted in the spring of 1937 and 1938 at the University Hill Farms, Madison, Wisconsin.*

Country or state of origin	1937 planting				1938 planting		
	No. of strains	June, 1938	Oct., 1938	May, 1939	No. of strains	Oct., 1938	May, 1939
Wisconsin	2	100	100	100	3	90	58
Oregon	0	—	—	—	1	95	35
Louisiana	0	—	—	—	3	96	2
Mississippi	0	—	—	—	1	100	3
Sweden	3	100	100	85	2	73	28
Poland	1	100	100	35	1	85	30
Denmark	2	100	100	97	3	87	52
England	1	100	100	20	1	100	20
New Zealand	7	100	100	20	5	99	7

In the spring of 1937 plots were established to test the survival of white clover in bluegrass pasture under different fertility, clipping, and grazing treatments.[4] Three strains of white clover, Louisiana White, Corn Belt White, and Kent Wild White, were seeded at the rate of 2 pounds per acre on good bluegrass sod. Check plots to which no seed was applied were also included. The Louisiana White, which in the first year appeared better than the other strains on the grazed plots and as good as the others on the clipped plots, winter-killed almost completely during the winter of 1938–39. Corn Belt White had a significantly better stand than the Kent Wild White on the grazed plots, while on the clipped plots there was no significant difference between these two strains.

SUMMARY AND CONCLUSIONS

In order to determine the adaptability of various domestic and foreign strains of red and white clover under Wisconsin conditions, some 63 red clover and 16 white clover strains were planted in the spring of 1937 and 80 red and 20 white strains in 1938.

The 1937 results show that European red clovers are decidedly inferior to domestic strains in their ability to produce a good stand the year of seeding when drought and high temperatures prevail. As a result the hay crop in 1938 was poor both in yield and in quality of hay, the latter due largely to a high percentage of weeds.

[4]This pasture experiment is a cooperative one with H. L. Ahlgren, F. W. Tinney, and E. A. Hollowell. A more complete separate report will be made at a later date.

The average yield in tons of cured hay per acre in 1938 for red clover strains from different sources was Wisconsin 3.35, Canada 3.55, Hungary 1.03, Poland 0.77, all Europe 0.96, and all United States 3.32.

The superior performance of Graham's Mammoth indicates that this strain is hardier under adverse conditions than the medium or two-cut types.

Strains of white clover of different origins varied considerably in adaptability to Wisconsin conditions. White clover strains from Louisiana and New Zealand winter-killed almost completely in small plots, in large field plots, and in pasture plots during the winter of 1938–39.

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BOOK REVIEWS

LAND DRAINAGE AND RECLAMATION

By Quincey Claude Ayres and Daniel Scoates. New York: McGraw-Hill Book Company. Ed. 2. XI+496 pages, illus. 1939. $4.00.

IN WRITING this book, which obviously is intended to serve as a text for college students of agriculture, the authors have succeeded in producing a treatise which is both elementary and comprehensive. The book is mainly an exposition of engineering practices as they are applied to land surveys, drainage, irrigation, and the control of soil erosion. In order to orient these practices properly, discussion has been included on such subjects as soils, rainfall and run-off, drainage and conservation districts, and principles of law.

Those who approved the first edition of this book will undoubtedly approve the second. The introduction has been re-written and thereby improved. Additional space has been devoted to soil erosion and its control, evidently in response to the impetus currently given this subject by governmental agencies. The chapter on land clearing has been modified and condensed. Other and minor changes appear throughout the text.

The book should appeal to soil conservation workers who recognize themselves to be inadequately trained in the engineering phases of their work. (C. S. S.)

AN OUTLINE OF BRITISH CROP HUSBANDRY

By H. G. Sanders. New York: Macmillan Company. VIII+348 pages, illus. 1939.

THE author, who is a lecturer in agriculture in the University of Cambridge, makes it clear in his preface that this book is, as the title states, an outline and not in any sense a complete treatise on crop husbandry. Data and detail have been subordinated and general principles stressed, since, as the author says, principles are sometimes lost sight of in attention to the details of husbandry prevalent in any particular farming district.

The text deals with rotations, manuring, weed control, tillage and seedbed preparation, choice and treatment of seed, sowing, cultivation, and harvest as applied to various crops. In addition, a chapter is devoted to cost analysis. Some bibliography is given at the ends of chapters, the references being very largely British.

The subject matter seems well constructed and, although written entirely from the British viewpoint, American agriculture can learn much from a concise outline of the principles underlying British crop husbandry. (R. C. C.)

COMMON BRITISH GRASSES AND LEGUMES

By J. O. Thomas and L. J. Davies. New York: Longmans, Green and Co. 124 pages, illus. 1938. $2.20.

THIS little book does in an excellent manner exactly what its authors apparently intended it to do, namely, it serves as a guide to the identification of the common grasses and legumes in the field. While it was written to meet the needs of farmers, agricultural schools, and certain classes in agricultural colleges, it contains much material of immediate value to agronomists and botanists.

Following three chapters giving a discussion of the morphology of the common British grasses, useful plant characters, and a key to the vegetative characters, some 66 different species are definitely discussed, and, of these, 44 are illustrated. The rather accurate and excellent illustrations are so arranged as to face the text material describing each species, an excellent scheme which one soon comes to appreciate when using the book in the field or classroom.

Another useful and valuable feature about the book is that the authors have added to the section dealing with distribution and economic value much new material, particularly that having to do with new findings in pasture improvement through the use of the grasses and legumes. Agronomists should find the book very useful. (M.T.M.)

INTRODUCTION TO THE BOTANY OF FIELD CROPS

By J. M. Hector. Johannesburg: Central News Agency, Ltd. Vol. I, Cereals; Vol. II, Non-Cereals. LXV+1127 pages, illus. 1936–38. 3.10.0.

IN these two very useful volumes the author has assembled a great wealth of material on a wide variety of plants often classed as field crops. The cereals are dealt with in the first volume and in the second volume the author takes up 13 families which are classed as non-cereals yet contain the leading crop plants of the world. Each of these families is dealt with separately and has a key immediately following the general though brief discussion of the groups or subdivisions discussed. This is followed by an excellent bibliography arranged alphabetically by authors. The completeness and effectiveness of the bibliography is revealed as one uses the text and there finds new citations as well as the older standard or dependable ones.

The excellence of the first volume is continued on through the second volume and the author seems to have fulfilled his aim as ably explained in the introduction in presenting from a systematic and structural veiwpoint the entire plant, anatomically, histologically, and cytologically. The text material is nicely supplemented by many more or less excellent illustrations which are well placed. There are 88 tables which give the most useful data mentioned in the text discussion.

While the agronomist might be mostly interested in the first volume, the second volume is so valuable an addition that it really seems necessary. Both volumes are well printed and attractively

bound. They are broad in their scope and viewpoint and will surely find a place which has been only partly filled by other texts. The investigator, advanced student in agronomy, and the post-graduate should find these two volumes exceedingly useful and valuable. (M. T. M.)

ROOT NODULE BACTERIA AND LEGUMINOUS PLANTS

By E. B. Fred, I. L. Baldwin, and Elizabeth McCoy. Madison, Wis.: Univ. of Wisconsin Press. 40 pages. 1939. 50 cents.

THIS is a supplement to the first publication bearing the same title and published in 1932, and contains a list of papers published in this field from 1932 to 1938. A few important papers overlooked in the first report are also listed. As an added feature and in response to suggestions received by the authors, the index is supplemented by a list of the scientific names of all plants cited in the original monograph and by an author index.

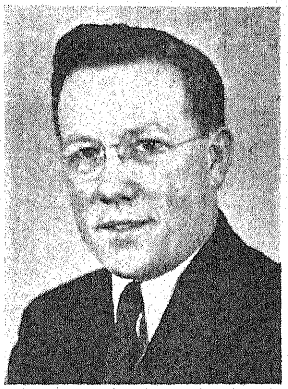
RESEARCH ON GRASSLAND, FORAGE CROPS, AND THE CONSERVATION OF VEGETATION IN THE UNITED STATES OF AMERICA

By R. O. Whyte. Herbage Publication Series, Bulletin 26. Imperial Bureau of Pastures and Forage Crops, Aberystwyth, Wales. 113 pages, illus. 1939. 5s.

THIS bulletin gives an account of research in forage crops, range management, and the botanical aspects of soil conservation in the United States. A detailed summary is given of the research projects in the Division of Forage Crops and Diseases of the Bureau of Plant Industry, the Regional Pasture Research Laboratory, the Range Investigations of the Forest Service, the Research of the Soil Conservation Service, and of the state agricultural experiment stations. Reference is made to the studies in progess under the auspices of the U. S. Golf Association. A report of the Division of Plant Biology, Carnegie Institution of Washington, gives details of some researches on factor and function in adaptation, and on climax, succession, and conservation. (F.B.S.)

FELLOWS ELECT FOR 1939

LEONARD DAVID BAVER



LEONARD DAVID BAVER was born on a farm near Miamisburg, Ohio, December 8, 1901. He received his B.S. degree from Ohio State University in 1923 and the M.S. degree in 1926. He was granted the Ph.D. degree by the University of Missouri in 1929.

He is a member of the American Society of Agronomy, the Soil Science Society of America, the International Soil Science Society, and the American Geophysical Union.

Assistant in Agronomy, Ohio Agricultural Experiment Station, 1923–28; Research Fellow in Soils, University of Missouri, 1928–29; Associate Soil Chemist, Alabama Agricultural Experiment Station, 1929–31; Associate Professor of Soils, University of Missouri, 1931–37; Professor of Agronomy, Ohio State University, 1937–. During 1936, Senior Soil Conservationist in the Soil Conservation Service.

Member of numerous committees of the American Soil Survey Association, of the American Society of Agronomy, and of the Soil Science Society of America, and American representative of the Soil Physics Section at the last meeting of the International Society of Soil Science.

He has published numerous papers dealing with soil structure, consistency, porosity, genesis, and morphology, the colloidal properties of soils, soil organic matter and its effect on soil structure, erosion, and crop production. He made the earliest use in this country of the quinhydrone method for the determination of soil acidity and has developed an electro-thermal method for the determination of soil moisture.

MERLE TRUMAN JENKINS

MERLE TRUMAN JENKINS was born at Brookings, S. Dak., January 4, 1895. He received his B.S. degree from the Oregon State College in 1916, shortly thereafter, joined the U. S. Army. In 1919 he entered the United States Bureau of Plant Industry as scientific assistant in corn investigations, being advanced through the various grades to his present position of principle agronomist in charge of corn investigations in 1934. He received his M.S. degree from Iowa State College in 1925 and the Ph.D. degree from the same place in 1928.

From 1922 to 1934 he was in charge of the corn investigations co-operative between the Iowa Agricultural Experiment Station and the Bureau of Plant Industry, U. S. Dept. of Agri-

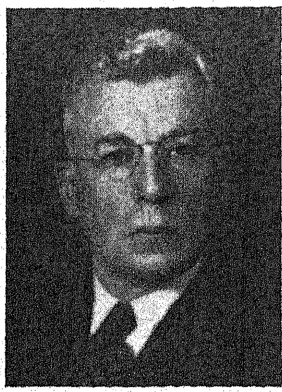
culture. During this time, Doctor Jenkins made notable contributions to the theory and practice of modern corn breeding, and also found time for genetic and physiologic research with corn, the results of which are reported in numerous papers.

Doctor Jenkins' most important agronomic contribution during this time probably was the development of the inbred lines of corn now used so extensively throughout the Corn Belt. One of these lines, L317B2, is probably the most resistant to drought of all lines so far developed, whereas his Iowa hybrid 939 is probably grown to advantage more widely than any other hybrid extant.

Since 1934 Doctor Jenkins' capability in handling his administrative responsibilities as leader of the Bureau's extensive corn investigations has permitted him to continue some personal research with corn which is bearing fruit.

Doctor Jenkins has taken an active interest in the affairs of the American Society of Agronomy for many years. He has organized symposia for the meetings, served on important committees, and been chairman of the Crops Section.

AUSTIN LATHROP PATRICK



Austin Lathrop Patrick was born in Scranton, Pa., August 23, 1889, and lived a part of his early life on a farm in northeastern Pennsylvania. He received his B.S. degree from Pennsylvania State College in 1913 and his M.S. degree in 1925. In 1931 he was granted the Ph.D. degree by Cornell University.

Doctor Patrick is a member of the American Society of Agronomy and of the Soil Science Society of America and of Sigma Psi, Phi Kappa Phi, and Gamma Sigma Delta honorary fraternities.

Scientist in Soil Surveys, U. S. Dept. of Agriculture, 1913–19; Assistant Professor, Associate Professor, and Professor of Soil Technology, Pennsylvania State College, successively, 1919–37. During this period he was in charge of the soil survey work in Pennsylvania and acted as Director of the short courses given at the College. From 1934 to 1937 he was "loaned" by the College to the Soil Erosion Service, later the Soil Conservation Service, and acted as Regional Director of the Service in Pennsylvania and was in charge of the development of the soil erosion experiment station at State College, Pa. From June 1937 to June 1939 Doctor Patrick was Chief of the Division of Watershed and Conservation Surveys of the Soil Conservation Service and since June 1939 has been acting as Assistant Chief of the Soil Conservation Service in charge of the divisions of surveys and project planning, with headquarters in Washington, D. C. He is the author of numerous publications in his field.

Doctor Patrick served as Secretary-Treasurer and as President of the American Soil Survey Association and was one of eleven soils men to be designated by Secretary of State Cordell Hull to represent the United States at the International Soil Science Congress in England recently. He has served on several committees of the American Society of Agronomy and was a member of the organizing committee of the Soil Science Society of America.

MINUTES OF THE THIRTY-SECOND ANNUAL MEETING OF THE AMERICAN SOCIETY OF AGRONOMY

THE thirty-second annual meeting of the Society was held in the Roosevelt Hotel in New Orleans, Louisiana, November 22, 23, and 24. There were 670 registered at the meetings and over 700 in total attendance. In addition a large number of ladies accompanied their husbands and enjoyed the hospitality and beauty of New Orleans.

The general meeting of the Society was held on Thursday morning, November 23, with President R. J. Garber presiding. W. C. Lassiter, Editor of the PROGRESSIVE FARMER, spoke on "The Social and Economic Problems of Southern Agriculture", and M. J. Funchess, Dean of Agriculture at Alabama Polytechnic Institute, discussed "Agronomic Problems of the South". Both papers were well received and will appear in an early number of the JOURNAL.

The annual dinner was held on Thursday evening with the address of the President, "The Agronomist, His Profession, and an Example of Coordinated Research", as the feature of the occasion.

The Crops Section held programs on Breeding, Genetics and Cytology; Physiology, Morphology, and Taxonomy; and miscellaneous subjects. There were five sessions on each of the three groups of subjects and a total of 87 papers was presented. In addition there were round table discussions and conferences.

The Soil Science Society held 14 sectional meetings with programs on soil physics, soil chemistry, soil fertility, soil genesis, morphology and cartography, and soil technology. There were 88 papers presented in addition to 7 presented at a joint session with the Crops Section. A general soils program was held on Thursday afternoon with the presentation of 5 papers.

The Auditing Committee appointed by President Garber consisted of Dr. F. B. Smith and Dr. H. H. Laude. The Nominating Committee consisted of President Garber as chairman and Dr. F. D. Keim, Dr. W. A. Albrecht, Prof. H. C. Rather, and A. M. O'Neal.

FELLOWS

Vice-president Alway announced the Fellows Elect and presented the certificates. Those elected were Dr. L. D. Baver, Dr. M. T. Jenkins, and Dr. A. L. Patrick. (See pages 1041 to 1042.)

OFFICERS' REPORTS

REPORT OF THE EDITOR

WHEN Volume 31 of the JOURNAL is completed it will contain approximately 1,100 pages and will present 108 papers, 22 notes, and 23 book reviews, in addition to numerous miscellaneous items that appear under the general heading of "Agronomic Affairs". At this writing 18 papers have been returned for one reason or another and sufficient material is in hand for the January 1940 number. Thus, we come to the end of another year of JOURNAL publication with what we regard as a satisfactory state of affairs, at least from an editorial point of view.

The Treasurer's report will show our financial status which we believe is also satisfactory, considering that extra demands were made upon the finances of the Society with the publication of the cumulative index for Volumes 21 to 30, inclusive, and with the allotment to the Editor of a small sum, shared by the Soil Science Society, for the employment of a part-time editorial clerk. Incidentally, this part-time assistance and the Editor's own item are now covered very largely by the advertising income of the JOURNAL. Practically all contracts for advertising have already been renewed for 1940 and one or two new advertisers are considering the JOURNAL for next year, so we would urge especially that you "mention the JOURNAL to advertisers".

The cumulative index has been fairly well received, but we have not yet recovered in its sale the entire cost of publication. We believe everyone who keeps a complete file of the JOURNAL will eventually want this useful tool which may be obtained for the very nominal sum of $1.00.

A new undertaking for your Editor this past year was the handling of the 1938 PROCEEDINGS of the Soil Science Society. The procedure for the editing and publishing of this volume had been so well conceived and so carefully worked out by Doctor Bradfield and his associates prior to our taking over last fall that it was largely a matter of following the lines laid down by these men. We are conscious, however, of certain shortcomings in the handling of Volume 3 of the PROCEEDINGS, some of which were beyond our control, to be sure; but we are hopeful for more prompt and more satisfactory service in this direction with increasing experience.

You may be interested in learning something about the magnitude of the sales of the several agronomic publications entrusted to our care. Almost every mail brings in orders for one or more of these publications and of course we are constantly being called upon to supply back numbers of the current volume of the JOURNAL to new members of the Society or to send the PROCEEDINGS to some one who paid his dues to the Soil Science Society. Just for your information, here are the figures since January 1st: Seven sets of the PROCEEDINGS of the First International Society of Soil Science; 9 bulletins of the Soil Survey Association; 244 orders for the indexes to the JOURNAL; 285 orders for back numbers of the JOURNAL; and 315 orders for different volumes of the PROCEEDINGS of the Soil Science Society.

Further correspondence was carried on during the year with the Editorial Advisory Committee with reference to enlarging the personnel of that committee and to expanding its functions still further as a review board for contributions to the JOURNAL. The services of the present members of the committee have been utilized throughout the year, along with those of others, in reviewing papers, but we feel that the time has come when the editorial policies of the JOURNAL, in so far as they have to do with the acceptance or rejection of papers, should be placed upon a somewhat more rigid procedure than now prevails. This is presumably a matter for the Editorial Advisory Committee and the Executive Committee to work out.

We are a bit concerned as to what the unsettled conditions abroad may do to our large and profitable foreign circulation. Thus far there have been no serious reverberations, but it would not be at all surprising to see many cancellations with the expiration of present subscriptions; in fact it will be most surprising if we do not suffer serious inroads in our foreign subscriptions. There are many men working in the various fields of agronomy in this country who are not yet members of this Society or subscribers to the JOURNAL. A little home missionary work would do much to offset here at home what we are likely to loose abroad.

A recent correspondent expressed regret that the JOURNAL did not have more personal items about the goings and comings of agronomists. To show that he was sincere in the matter, he submitted several items from his own institution which will appear in an early number of the JOURNAL. Doubtless we have been remiss in not encouraging more "letters to the Editor", and it goes without saying that we would welcome more news items. To stimulate anew interest in this section of the JOURNAL, we shall soon ask each Department of Agronomy to designate someone in their organization who will assume responsibility for seeing that we are kept informed on changes in personnel and in events of interest to other agronomists that transpire within their group.

On behalf both of the Society and of the JOURNAL, we would express our appreciation of the very efficient discharge of the multitudinous duties of his office by our Secretary-Treasurer, Doctor G. G. Pohlman. The JOURNAL could survive for sometime without an Editor, but the affairs of the Society would bog down very quickly without the constant and close supervision of the Secretary's office which we have enjoyed during the past year.

Respectfully submitted,
J. D. LUCKETT, *Editor*.

REPORT OF THE SECRETARY

THE membership changes in the Society since the last annual report are briefly summarized as follows:

Membership last report		1,230
New members, 1939	86	
Reinstated members	63	
Total increase	149	
Dropped for non-payment of dues	127	
Resigned	28	
Died	7	
Mail returned unclaimed	12	
Total decrease	174	
Net decrease		25
Membership, October 31, 1938		1,205

The subscription list has increased during the year as shown by the following figures:

Subscriptions, last report		660
New subscriptions, 1939	129	
Subscriptions dropped	102	
Net increase		27
Subscriptions, October 31, 1939		687

The paid up membership and subscription list by states and countries is as follows:

	Members	Subscriptions
Alabama	10	1
Arizona	8	3
Arkansas	9	4
California	40	10
Colorado	17	1
Connecticut	9	2
Delaware	4	0
District of Columbia	87	5
Florida	17	3
Georgia	16	0
Idaho	8	1
Illinois	45	9
Indiana	25	3
Iowa	36	2
Kansas	42	3
Kentucky	10	4
Louisiana	19	4
Maine	5	1
Maryland	17	5
Massachusetts	11	4
Michigan	21	5
Minnesota	25	5
Mississippi	12	1
Missouri	17	4
Montana	8	5
Nebraska	31	3
Nevada	2	1
New Hampshire	2	0
New Jersey	15	4
New Mexico	5	2
New York	47	11
North Carolina	16	5
North Dakota	12	1
Ohio	47	4
Oklahoma	11	5
Oregon	10	3
Pennsylvania	18	6
Rhode Island	7	0
South Carolina	14	2
South Dakota	7	1
Tennessee	14	2
Texas	49	11
Utah	10	6
Vermont	3	0
Virginia	23	3
Washington	20	4
West Virginia	10	1
Wisconsin	31	2
Wyoming	7	1
Alaska	0	1
Hawaii	8	8
Philippine Islands	1	2
Puerto Rico	3	2
Africa	4	28

	Members	Subscriptions
Argentine	8	10
Australia	1	26
Brazil	0	5
British Guiana	0	1
British West Indies	1	1
Canada	14	39
Ceylon	0	3
Chile	2	1
China	3	13
Columbia	1	0
Costa Rica	1	0
Cuba	1	4
Denmark	2	0
Dutch East Indies	0	6
Egypt	1	3
England	3	13
Estonia	0	1
Fed. Malay States	1	3
Fiji	0	0
Finland	0	5
France	1	11
Germany	2	7
Greece	2	1
Holland	0	4
Honduras	1	1
Hungary	0	0
India	5	20
Indochina	0	1
Ireland	0	2
Italy	0	12
Japan	6	76
Jugoslavia	1	1
Mauritius	0	1
Mesopotamia	0	0
Mexico	1	0
New Zealand	0	6
Norway	0	2
Palestine	2	0
Persia	1	0
Peru	2	1
Poland	2	1
Portugal	1	4
Roumania	0	1
Scotland	2	1
Siam	2	1
Spain	0	1
Sweden	0	2
Switzerland	1	1
Turkey	2	2
Uruguay	1	0
U. S. S. R.	6	95
Venezuela	1	2
Wales	0	3
	1,026	598

The number dropped for non-payment of dues is about the same as in 1938 as is also the number resigned. A large number of the subscribers who have been dropped are from China, Japan, and Russia. There are 179 members and 89 subscribers who have not yet paid their 1939 dues. We hope that they will soon pay

their dues and continue in the Society. There have been a number of members whose mail has been returned. These are principally foreign members, although a few are in the United States.

The decrease in membership is largely the result of a much smaller number of new members than last year. Apparently we have not given enough attention to this part of the work. A number of members have been very active in securing new members. The Society appreciates your cooperation in helping in this way.

The number dropped for non-payment of dues seems too high. I would appreciate any suggestions as to how the old members can be retained. A few have criticized the Society for dropping their names from the rolls without sufficient notice. However, no one has been dropped who has not been at least a year in arrears. During this time at least two notices have been sent.

At times during the past year it seemed that the Secretary's office was pretty slow in attending to orders and answering correspondence. However, you were very patient and eventually we got things straightened out. I appreciate your cooperation. I also wish to thank those in charge of the various programs for the promptness and order in which they sent in the programs. This was especially helpful in speeding up the delivery of the programs to the members.

Respectfully submitted,
G. G. POHLMAN, *Secretary*.

REPORT OF THE TREASURER

I BEG to submit herewith the report of the Treasurer for the year, November 1, 1938, to October 31, 1939.

RECEIPTS

Miscellaneous	$2,820.84
Advertising income	783.20
Reprints sold	1,796.82
Journals sold	214.43
Subscriptions, 1939	2,345.00
Subscriptions, 1938	65.10
Subscriptions, 1939 (new)	696.32
Subscriptions, 1940 (advanced)	180.00
Dues, 1939	4,310.16
Dues, 1938	485.75
Dues, 1939 (new)	417.26
Dues, 1940 (advanced)	91.50
Index	172.08
Miscellaneous (S.S.S.A.)	75.50
Sale of Soil Survey Bulletins (Marbut Memorial Fund)	141.05
Sale of Proceedings, Vol. I (1936)	87.50
Sale of Proceedings, Vol. II (1937)	398.76
Dues and subscriptions S.S.S.A. (old) 1939	2,203.16
Dues and subscriptions S.S.S.A. (new) 1939	292.56
Dues and subscriptions S.S.S.A. (advanced) 1940	13.50
Membership only S.S.S.A., 1939	20.50
Sale of Proceedings First International Congress of Soil Science	95.75
Fees, I.S.S.S., 1939	704.56
Fees, I.S.S.S., 1939 (new)	107.50
Fees, I.S.S.S., 1938	40.00
Fees, I.S.S.S., 1940 (advanced)	9.50
Total receipts	$18,568.30
Balance in cash, November 1, 1938	2,723.64
Total income	$21,291.94

DISBURSEMENTS

Printing the Journal, cuts, etc.		$ 9,707.13
Salary, Business Manager and Editor		750.00
Postage, Business Manager and Secretary		184.81
Printing, miscellaneous		317.85
Express on Journal and Proceedings		18.72
Mailing clerk and stenographer		769.39
Refunds, checks returned, etc.		111.42
Miscellaneous, expenses annual meetings, etc.		3,266.26
S.S.S.A. expenses, printing Proceedings, etc.		3,408.53
I.S.S.S. expenses, fees to Dr. Hissink, etc.		784.69
Total disbursements		$19,318.80
Total income	$21,291.94	
Less total disbursements	19,318.80	
Balance in checking account Oct. 31, 1939	$ 1,973.14	
Balance in trust certificate	267.71	
Balance in savings bonds	2,250.00	
Total assets		$ 4,490.85

Respectfully submitted,
G. G. POHLMAN, *Treasurer.*

AUDITING COMMITTEE

THE Committee examined the books and found them to be in order and the accounts to be correct as reported by the Treasurer.

Respectfully submitted,
H. H. LAUDE
F. B. SMITH, *Chairman*

OTHER COMMITTEE REPORTS

EDITORIAL ADVISORY COMMITTEE

THE Editorial Advisory Committee made the following recommendation: That it be replaced by an Editorial Board made up as follows: An Editor, an Associate Editor in Crops and an Associate Editor in Soils, and from three to five Consulting Editors in both soils and crops.

The Editor and the Associate Editor in Crops and Associate Editor in Soils shall be selected by the Executive Committee of the Society. They shall be reappointed from year to year, but their tenure shall whenever possible be extended over several years. The Consulting Soils Editors and the Consulting Crops Editors shall be specialists in the various subdivisions of their respective subjects. They shall be selected by the Associate Editor in charge of the respective field.

All papers submitted for publication in the JOURNAL shall be directed to the Editor. He in turn shall refer all papers dealing predominantly with soils to the Associate Editor in Soils and all papers dealing predominantly with crops to the Associate Editor in Crops. The Associate Editors shall, with the aid of their respective Consulting Editors, review the papers submitted to them and shall make such recommendations to the Editor as they see fit regarding their suitability for publication in the JOURNAL.

The Editor shall, as in the past, be responsible for preparing the manuscripts for the printer and for handling all correspondence with the authors of papers.

R. J. GARBER J. D. LUCKETT
MERLE T. JENKINS I. L. BALDWIN
RICHARD BRADFIELD, *Chairman*

BIBLIOGRAPHY OF FIELD EXPERIMENTS

THE committee has compiled a bibliography of 82 titles of the more important contributions on the methodology of and interpretation of results of field plat experiments, either reported since or not included in the revised bibliography published in the JOURNAL (Vol. 25: 811–828, 1933; and the additions in Vol. 27: 1013–1018, 1935; Vol. 28: 1028–1031, 1936; Vol. 29: 1042–1045, 1937; Vol. 30; 1054–1056, 1938).

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F. R. IMMER
H. M. TYSDAL
H. M. STEECE, *Chairman*

SOIL TILTH

THE Joint Committee on Soil Tilth has been given the assignment of co-operating with a similar committee in the American Society of Agricultural Engineers to help determine or suggest a "measure of soil condition or tilth". The most difficult part of this assignment is to thoroughly understand what is meant by tilth. It is necessary to define tilth before methods for characterizing it can be designated. Due to the fact that most concepts of tilth do not agree in all respects, it will not be the purpose of this report to propose a definition of tilth to be used as a standard. An attempt will be made, however, to characterize the physical condition of the soil which is included in the concept of tilth.

Tilth is commonly defined as "the physical condition of the soil in its relation to plant growth". Let us visualize what this definition implies. In the first place, it is obvious that soil structure relationships constitute a large part of this physical condition; adequate aeration, sufficient moisture, ready infiltration of rainfall, etc. are characteristics of good tilth. But, does tilth only refer to structural relationships? When one thoroughly analyzes tilth he is immediately impressed with the fact that tilth also includes certain phases of soil consistency.

A soil in good tilth from the point of view of structure is generally described in terms of consistency. For example, such a soil is said to be mellow and friable; it handles easily. Friability is one of the major forms of soil consistency. It represents that stage in the soil-moisture curve where there is sufficient moisture around the particles to overcome the cohesive forces between the particle surfaces but not enough of a moisture film to cause plasticity. Therefore, it seems that we define tilth on the basis of certain structural properties of the soil that are manifested within a given range of soil consistency. In other words, we designate first the consistency range and then define the soil structure relationships that are involved in tilth within this range. For example, if one examines a silty clay loam soil when it is too wet or too dry, the impression of good tilth is rarely obtained. The soil does not handle well in either case and conditions are not favorable for good plant growth.

It is significant to point out that the range of friability in which tilth reaches an optimum from the standpoint of plant growth also is the same range in which the soil can be tilled with the least output of power and with the best effects upon granulation. In other words, even though tilth is defined primarily on the basis of plant growth effects, the physical conditions so characteristized in good tilth for plant growth are usually, not always, favorable to good tillage. In many instances, tillage is responsible for the achievement of good tilth.

Therefore, irrespective of how we define tilth, let us keep in mind that it refers to certain structural conditions of the soil within a given range of consistency.

Various methods have been proposed to measure soil tilth. Keen and his associates in England have attempted to use the size-distribution of various clods as a measure of tilth. Soils were screened dry in the field. This technique has been modified recently along the lines of the Russian investigators, who wet-sieve the soil in benzene. The English workers attach considerable importance to the amount of material finer than ⅝ inches in diameter.

Several Russian investigators have emphasized the importance of granulation and porosity as measures of tilth. Most of their results indicate that a seedbed constituted of aggregates from 2 to 3 mm. in diameter is the best for plant growth. The soil pore space should be about equally divided between capillary and non-capillary pores. When the non-capillary porosity is lower than 10% by volume of the total soil, there is poor tilth. Von Nitzsch of Germany also employs pore space as a criterion of good tilth.

Yoder of Alabama and Baver of Ohio have obtained a considerable amount of data to show that the non-capillary porosity of the soil is a reliable index of tilth in relation to plant growth. The former has shown that cotton yields on artificially prepared seedbeds are definitely associated with non-capillary porosity of these seedbeds. The latter has observed that the production of greenhouse soils and sugar beet soils are closely related to the non-capillary porosity. Of course, non-capillary porosity is related to granulation in most cases.

Henin of France has used a penetrometer to obtain an index of tilth. This instrument measures the force of penetration of a metal point into the soil as a function of depth. The force required for penetration is considered an index of tilth. Schofield and his co-workers in England have proposed that compressibility be used to measure tilth. The more that a soil can be compressed, the better the tilth; the amount of compression in this case denotes the extent of looseness.

The methods of Henin and Schofield measure both consistency and structural effects. Penetration and compressibility are primarily dependent upon soil consistency but vary with structure. In other words, for a given soil structure, penetration and compressibility will vary with consistency. Therefore, although these types of determinations offer considerable possibilities for obtaining an over-all measure of tilth, they have not been characterized adequately enough as yet in terms of other soil properties.

Methods based upon granulation and porosity seem to this Committee to offer the most promising means at the present for characterizing soil tilth. Determinations of porosity must include not only the total porosity but also the relative distribution of the large and small pores. Cores of soils in their natural structure should always be used. The ideal technique would be to obtain a complete pF curve (size-distribution of pores) on each core sample. This requires considerable time. In case the obtaining of a complete curve is not possible, sufficiently reliable results can be had by determining the non-capillary porosity as the difference in the air capacity at zero tension and at a pF of 1.5 to 2.0. A clod or aggregate

analysis of the seedbed will undoubtedly give valuable supplementary data to help interpret the porosity results. Such an analysis may be made either by dry sieving, sieving in benzene, or sieving in water. The stability of a given tilth condition can probably be estimated from the differences between sieving in water and in benzene.

Therefore, this Committee recommends that the following measurements serve as an index of tilth, with the most desirable first:

1. Determination of total capillary and non-capillary porosity on undisturbed core samples of the soil.
2. Aggregate and clod analysis of the soil.
3. From a purely research point of view to obtain any information on penetration or compressibility that it might be feasible to procure.

J. F. LUTZ — R. J. MUCKENHIRN
H. E. MIDDLETON — L. D. BAVER, *Chairman*

VARIETAL STANDARDIZATION AND REGISTRATION

DURING the year, the Committee registered four varieties of wheat, five varieties of oats, one variety of barley, and one of cotton, as follows:

WHEAT

Wabash, Reg. No. 324, developed cooperatively by the Purdue University Agricultural Experiment Station and the U. S. Department of Agriculture.

Renown, Reg. No. 325, Coronation, Reg. No. 326, and Regent, Reg. No. 327, developed by the Dominion Rust Research Laboratory, Cereal Division, Winnipeg, Manitoba, Canada, of the Dominion Experimental Farms System.

OATS

Boone, Reg. No. 87, Hancock, Reg. No. 88, and Marion, Reg. No. 89, developed in cooperative experiments by the Iowa Agricultural Experiment Station and the U. S. Department of Agriculture.

Fulwin, Reg. No. 90, and Tennex, Reg. No. 91, developed by the Tennessee Agricultural Experiment Station.

BARLEY

Rex, Reg. No. 8, developed by the University of Saskatchewan, Saskatoon, Sask., Canada.

COTTON

Texacala, Reg. No. 35, developed by John D. Rogers, Navosota, Texas.

Descriptions of these varieties, and the yields and other records that form the basis for registration, are being prepared for publication in the JOURNAL.

Requests have been received for the registration of improved varieties of flax, sweet clover, and alfalfa. These requests were received at too late a date to circularize all members of the committee. In order to expedite the registration of these three crops, the committee requests authorization by the Society to approve their registration when, after canvassing the entire committee membership, such registration is deemed desirable. The committee also desires authorization by the Society at this time for preparing necessary rules and regulations, and specific requirements, for registering flax, sweet clover, and alfalfa, and also requests that

the President of the Society be authorized to appoint members of the Committee on Varietal Standardization and Registration who shall serve as specialists for handling the registration of the three crops.

H. B. Brown	H. K. Hayes	T. R. Stanton
J. Allen Clark	R. E. Karper	G. H. Stringfield
E. F. Gaines	W. J. Morse	M. A. McCall, *Chairman*

EXTENSION PROGRAM

WE ARE pleased to report the largest attendance of extension agronomists at any meeting in the history of the Society. The large attendance of extension agronomists made possible several valuable regional and subject matter conferences as follows: (a) Conference on production of winter legume seed including problems inherent in AAA grants of aid; (b) conference on seed certification in the South; and (C) conference on policies concerning distribution of new alfalfa varieties. There may be similar problems which will make highly desirable attendance of extension agronomists at future meetings.

We recommend (a) that the name of the committee on Extension Program be changed to read, Committee on Extension Participation; and (b) that the Chairman of the Committee be a member of program committees.

J. S. Owens	Earl Jones
O. S. Fisher	J. C. Lowery, *Chairman*

STUDENT SECTIONS

THE addition of the University of Tennessee to membership in the Student Section of the American Society of Agronomy makes a total of 19 institutions having chapters.

The national officers of the Student Section issued a news-letter early this fall. A meeting is planned at the time of the International Grain and Hay Show in Chicago.

Some 85 essays were entered in the Society's essay contest. The topic for this year's contest was, "The Work of Early American Agronomists". The authors of the 10 best papers were: 1, Melvin H. Kreifels, University of Nebraska; 2, George R. Page, University of Minnesota; 3, Emil O. Haudrich, University of Illinois; 4, Loren E. Juhl, University of Illinois; 5, Lawrence Treakle, University of Nebraska; 6, Carl A. Rovey, University of Arizona; 7, C. Rudolph Gustafson, University of Minnesota; 8, Benjamin Westrate, Michigan State College; 9, Ernest J. Guilloud, Jr., Texas A. & M. College; and 10, Harold Johansen, University of Minnesota.

It is recommended that the abstracts of the three best papers be printed in the Journal as a part of this report.

The committee proposes that the Society continue to sponsor the essay contest for another year and urges that members of the Society stimulate more students to participate in this activity.

G. H. Dungan	J. W. Zahnley
A. L. Frolik	H. K. Wilson, *Chairman*
J. B. Peterson	

THE WORK OF AN EARLY AMERICAN AGRONOMIST

By Melvin H. Kreifels, University of Nebraska

DR. THOMAS LYTTLETON LYON probably did more outstanding work in the field of agronomy than did any other man of his time. Most of his work was done in soils with emphasis on soil nitrates. His outstanding contribution to nitrogen research has been to develop a fuller and more fundamental knowledge of the natural factors which control the supply of nitrates in the soil. His investigations include the influence of cropping system on nitrate formation, the influence of soil moisture and tillage operations on nitrate production, factors which contribute to the loss of nitrates by leaching, influence of green manures on supply of nitrates and of total nitrogen in the soil, and the effect of mechanical conditions of the soil on the availability of sodium nitrate.

From his work Lyon was able to draw conclusions which have been used to this day. The plant has a definite effect upon the soil solution. The relative quantities of certain anions and cations in solution influence the rate of the nitrifying process. Organic matter affects bacterial activity which brings about the transformation of energy. Alfalfa soil produces nitrates more rapidly than does timothy soil because of the direct effects of the plant on nitrate production, however there is little difference in the total amount of nitrogen present in the two soils. The green plants and the organisms in the soil compete for the nitrogen present. Part, or possibly all of the nitrogen which is utilized by the organisms is not lost but remains in the soil.

The amount of lime in the soil does not affect the loss of nitrates by leaching, but it does affect the loss of magnesium. Under normal conditions the total quantity of bases is less in drainage water of limed soil, however the presence of potassium sulfate increases the loss of calcium by leaching.

At Nebraska Lyon worked on wheat and meadow and forage crops. In breeding of wheats he found that the gliadin and glutenin content of wheats could be increased along with an increase in yield. By selecting over a period of years, yields of wheat high in nitrogen could be raised to the level of that which the heavy large kernels produced. Generally the production of nitrogen in wheat per acre is greater in dry years. Lyon found brome grass to be best adapted to Nebraska conditions with the exceptions of meadow fescue and orchard grass. Alfalfa is the best forage plant, its value lying chiefly in the production of hay.

While at Nebraska Lyon was instrumental in obtaining cooperative experiments between the U. S. Dept. of Agriculture and the several stations scattered throughout the United States. He published several books. His grain grading texts and his soil books are used in almost every agricultural college.

THE WORK OF AN EARLY AMERICAN AGRONOMIST

By George R. Page, University of Minnesota

WILLET MARTIN HAYS was born October 19, 1859 on a farm in Hardin County, Iowa. When he was 12 years of age, his father died, and he and an older brother became the active operators of the farm supervised by their mother. This was his frontier.

While a student at Iowa State College, he was given part-time employment on field crops experiments, thus gaining his first insight into scientific methods. Upon graduation from Iowa State College in 1885, he served for a year as an assistant to Mr. S. A. Knapp, then agriculturist at the Iowa State College and Experiment Station. It was at this period that agitation for experiment station work was at its

height. As a consequence, Hays found himself in an atmosphere saturated with the idea of science in its application to agriculture, and he became thoroughly inbred with a desire to promote this type of research and education.

The research frontier was opened to Hays by the passage of the Hatch Act in 1887, which marked the advent of federally endowed experiment station work. The organization of state experiment stations proceeded rapidly and created a demand for men trained in science and in agriculture. Hays was drafted when the Minnesota School of Agriculture was organized in 1888. He was appointed to an instructorship in agriculture in the school and served as assistant agriculturist in the Experiment Station under Director E. D. Porter.

Here he found two frontiers which strongly stimulated his imagination and ambition. His training and experience were such as to fit him for just such a situation. With characteristic foresight and vigor he began the attack. His first experiments were a study of the root habits of corn and other plants, which led to a new understanding of the principles involved in tillage. His contributions to these subjects proved stimulating to workers in other stations and led to definite improvement in tillage operations and in the methods of crop production.

Hays conceived the idea that "there are Shakspears among plants". Recognizing the individual plant as a unit of improvement and being cognizant of the effects of hybridization, he set about finding ways to breed plants so that he might "find the Shakspears".

Introductions of varieties and samples of wheat were made and approximately 200 studied as early as 1889. Field and laboratory methods were developed for planting, harvesting, and studying the progeny of selections and a standardized program of breeding methods with small grains was formulated. The importance of quality was recognized and milling and baking studies were essential part of the early wheat-breeding program.

The importance of selection was clearly recognized. The methods adopted for self-pollinated plants consisted of an initial selection of promising individuals in field plots and their progeny study in centgener plots, e.g. 100 plants. Among commercially important early production of Minnesota plant breeders were two varieties of wheat, Improved Fife (Minn. 163) and Haynes Bluestem (Minn. 169) and Minn. No. 13 Corn. Of equal or greater potential value was the emphasis on the scientific importance of attacking problems in plant breeding on the basis of learning the fundamental principles involved.

Recognizing the influence of environment in affecting changes in plants and in bringing out new adaptation, Hays advocated the establishment of branch stations. The five branch agricultural experiment stations of Minnesota stand as a monument to his wisdom and foresight.

THE WORK OF EARLY AMERICAN AGRONOMISTS

By Emil Haudrich, University of Illinois

AGRICULTURE always was, and still is, the most important field of science. Our knowledge of this field at present is still rather limited, although for years men have spent their entire lives uncovering facts relating to the science of agriculture.

Cyril George Hopkins was one of these men. He was born upon a farm near Chatfield, Minnesota, in 1886. In 1894 he came to the Agricultural Experiment Station of the University of Illinois. He was a hard and conscientious worker and soon became a prominent man there.

He first worked on plant improvement but soon shifted his interests to soils where he did his most outstanding work. He won renown for advocating the Illinois system of permanent agriculture which recognizes plant food as the limiting factor in crop production. In furtherance of his teachings Doctor Hopkins established experimental fields in various parts of the state and was also instrumental in making the first soil survey in Illinois.

The outstanding characteristic of Doctor Hopkins was that he took special pains to make his findings and his teachings practical and understandable, so that every farmer could put them into practice and benefit directly therefrom. When we think of the things that he has done, and what the farmers who practiced his teachings have done, we can see the real significance of his work. By his thorough and accurate scientific research, his practical application of his findings, and by the self-sacrificing way in which he preached the gospel of soil fertility, he won the respect and confidence of scientists and farmers alike.

Doctor Edward Murray East was another early American agronomist who did much for agriculture. His chief interest was plant breeding, on which he was an authority. He was born at DuQuoin, Illinois, in 1879. He started his career at the University of Illinois, but did his most outstanding work at the Connecticut Experiment Station, and also at Harvard University.

Doctor East did some research work on the improvement of such crops as potatoes and tobacco, but his chief interest was corn. He was one of the first breeders who did extensive research to determine the application of Mendel's Laws of Heredity to our farm crops.

He began experiments in 1905 to determine the results of inbreeding and hybridizing corn. When we realize that as early as 1909, a method for the commercial utilization of hybrid corn was outlined that differs only in minor details from that now in use, we can appreciate the work of Doctor East in this field of genetics.

When we consider that he developed a scientific method of corn breeding, and contributed greatly to the establishment of the laws underlying the inheritance of measurable characters, we can readily see why he is considered among the great scientists of America.

Through the pioneering work of our early American agronomists the cornerstone of scientific agriculture has been laid. Now it is the task of present and future agronomists to build on this foundation.

FERTILIZERS

Subcommittee on Soil Testing.—During the year the Subcommittee on Soil Testing, with the help of the Division of Soil Chemistry of the U. S. Bureau of Plant Industry, assembled a collection of 31 standard soil samples of widely varying genetic and geographic origin. Sub-sample collections were submitted to workers in several states for correlative testing, the understanding being that workers were to employ any desired methods and report their results to the chairman of the Subcommittee. Preliminary study of 15 sets of data so far submitted shows a fair degree of consistency between the results of different workers and between different methods. There are, however, rather clear indications that the same technics cannot be employed saitsfactorily with all soils, also that standards of interpretation vary considerably among individual workers. It is planned to continue this work and it is hoped that when the results of chemical studies now being made on these soils by the Division of Soil Chemistry are available, the

reasons for variations and apparent discrepancies among methods may be elucidated. Sets of check soils for correlation of "quick test" methods are still available for distribution on request through Dr. H. G. Byers, Division of Soil Chemistry, Bureau of Plant Industry, Washington, D. C.

M. F. MORGAN, *Chairman*

Subcommittee on Fertilizer Grades.—Through the cooperation of a group of fertilizer manufacturers operating well over 100 factories and supplying approximately 45% to 50% of the fertilizer used in this country, exclusive of the Pacific Coast, confidential data were obtained concerning the cost of manufacturing and marketing a large number of fertilizer analyses. These data reveal that as the number of fertilizer grades is increased there is a marked increase in cost of production due to loss of time in making changes from one analysis to another. This loss may amount to from one-fourth to one-half the possible output of a plant depending on the number of changes made and contributing factors. Increased capital investment for storage, loss of power, cost of registration, loss of time in printing bags, and increased cost of chemical control make further substantial additions to the cost of supplying a large number of analyses. The Committee is indebted to Mr. D. D. Long for collecting and summarizing the data.

A committee in the northeastern states under the leadership of Professor M. F. Morgan has held several conferences of representatives of the industry, agronomists, and members of the Soil Improvement Committee of District 1. It was agreed to work toward (1) a minimum of 20 units in accepted grades, (2) a minimum of 8% nitrogen or potash or the two combined in accepted grades, (3) publicity and endorsement of agronomists' recommended ratios for specific crops. A list of 12 ratios was agreed upon as generally suitable for New England conditions and acceptable grades were approved for the 1940 season. Three ratios were accepted as meeting the special needs of tobacco in New England.

Middle Atlantic states have also come to an agreement concerning a list of ratios and grades to be recommended in the various states.

A comparison of the analysis and number of grades recommended by agronomists and offered for sale in the various states has been made. The number of grades recommended in a state varies from 10 to 30. The number of grades offered for sale in a state runs from 10 to 109. In one state, 14 of the recommended grades were not offered for sale and the number of unrecommended grades offered for sale varied from 16 to 91. The number of grades recommended in both of two adjoining states varied from 3 to 19. The number of grades offered for sale in only one of two adjoining states ranged from 11 to 114.

There is evidently much opportunity for agronomists to cooperate with each other and with the industry in unifying recommendations and for representatives of the industry to restrict offerings.

C. E. MILLAR, *Chairman*

Subcommittee on Symptoms of Malnutrition in Plants.—The members of the Subcommittee have spent the year collecting and preparing suitable material for the proposed book on "Deficiency Symptoms". Mr. Gove Hambidge of the U. S. Dept. of Agriculture has been selected to edit the material and has already gone over the subject matter for the tobacco chapter. A conference was held with a possible publisher who reacted favorably in regard to handling the publication. It is hoped that other publishers can be approached when the chapter authors submit additional copy. The financial sponsorship of the book is now finally assured.

At a meeting of the Subcommittee in Washington on October 13 good progress on preparation of material was reported by all chapter authors and it was the opinion of most authors that they could have their material ready by January 1, 1940.

J. E. McMurtrey, *Chairman*

Subcommittee on Fertilizer Reaction.—The Subcommittee has continued to sponsor investigations on the factors influencing the availability of different sources of magnesium in complete fertilizers. This work was completed during the year and was reported to the Association of Official Agricultural Chemists at a recent meeting in Washington. The data are being utilized by that organization in evaluating different analytical methods for available magnesia in complete fertilizers. The Subcommittee continues to sponsor field experiments on several problems relating to the use of acid vs. non-acid forming fertilizers. In this they have received fine cooperation from several state experiment stations and the Division of Soil Fertility of the Bureau of Plant Industry.

F. W. Parker, *Chairman*

Subcommittee on Methods of Fertilizer Application.—The Subcommittee has continued to participate in the work of the National Joint Committee on Fertilizer Application. The extensive program on machine placement of fertilizers has been continued and last year included 157 experiments at 70 locations in 26 states and involved 30 different crops. Increased attention is being given to fertilizer placement on organic soils and on irrigated land. Studies dealing with localized applications of fertilizer simultaneously at two depths instead of the customary single depth give promise of better efficiency under varying moisture conditions. Promising results have also been obtained in experiments in which the three fertilizing elements have been placed differentially with respect to the seed or plant, also in experiments in which nitrogen fertilizers have been incorporated by plowing under with crop residues. Increased attention is being given to certain of the more fundamental conditions affecting fertilizer application and it is expected that these studies will permit greater refinement in methods to meet variations in climate and soil.

Robt. M. Salter, *Chairman*

PASTURE IMPROVEMENT

The Joint Committee on Pasture Improvement during the past year has been concerned primarily with the inter-Society organization and the development of a procedure for going forward with the joint work on the comparative nutritive value and relative cost of forage and other crops. Your previous Chairman, P. V. Cardon, succeeded in bringing about the organization of an inter-Society Committee with representatives from the American Society of Animal Production, American Dairy Science Association, Canadian Committee on Pasture and Hay, and the American Society of Agronomy. Each Society has given, or will give, consideration to the joint problem at its summer or fall meetings.

A "Grassland Conference" was held in conjunction with the joint summer meetings of the Northeastern and Corn Belt Sections of the Society at Wooster, Ohio. In addition to a number of other topics of interest to specialists concerned with grassland management and improvement, there was a discussion of "methods for evaluating pastures in relation to each other and to other harvested feed crops".

A report on the conference was prepared, mimeographed and distributed to those in attendance at the meeting, and others interested in pasture improvement. A resolution was passed to the effect "that future conferences be held, and that reports of the discussions be forwarded to Experiment Station Directors and all other interested individuals". The following extract from the report of the "Grassland Conference" indicates the nature of the discussion on the comparative nutritive value of forage and other crops:

"Pasture improvement based on findings of Experiment Station workers and others has not found as wide a reception among farmers as the condition of millions of acres of pasture land would appear to warrant. This is believed to be due in large part to the scarcity of information relative to (1) the value of pasture crops in relation to each other and (2) the value of pasture crops in relation to other harvested feed crops when grown under similar soil and cultural conditions. At present 13 widely different methods are used in evaluating pastures and improved pasture practices. There is need for a standardization of methodology. Any method of evaluation should be based on livestock and livestock products produced and must consider maintenance, production, gains or losses in live weight and supplementary feed required.

"It was suggested that the feeding value of different pasture crops be determined by (1) grazing on comparatively small replicated areas under field conditions, (2) feeding the harvested green forage under standardized controlled conditions, (3) feeding the harvested forage as hay and (4) feed the harvested forage as silage."

Another grassland meeting was held at the Great Basin Branch Station of the Intermountain Forest and Range Experiment Station, Ephraim, Utah. A report on the meeting was made by the U. S. Forest Service, under the title "Proceedings of the Range Research Seminar, July 10–22, 1939". Special consideration was given to nutritional problems. The following extract indicates the nature of the discussion:

"The necessity for detailed information on nutritional problems of range livestock is becoming more and more evident as range management progresses. The utilization standards studies in particular have shown the need for more definite information on nutritional values of range forage plants through the season and in relation to different degrees of use. Animal nutrition studies have been the subject of experimentation for a great many years by State Agricultural Experiment Stations.

"Most of the effort of these institutions, however, has been expanded on animal nutrition studies under feed lot rather than range conditions. Before the Agricultural Experiment Stations can expand their program of research to include nutritional studies of range plants and animals, additional funds, equipment and personnel will be needed. The degree of participation by the Forest Service should depend largely on the adequacy of coverage within the field of endeavor; that is, if the state institutions satisfactorily provide the needed information on nutritional phases, participation then should be restricted to cooperative assistance.

"The tentative program of western-wide determination of chemical analyses of range plants prepared in 1938 by the Bureau of Animal Industry and the Forest Service represents a beginning in the interpretation of range nutritional problems. As a basis for preparation of further programs of this nature your committee desires to list some of the specific nutritional problems of range livestock and range plants that need investigation: (1) Forage requirements of the grazing animal; (2) Nutritional values of range forage plants in relation to degree, season, kind of

use, past treatment, and soils; (3) Relation of nutritional values of various vegetation types to forage acre requirements and to the growth, maintenance and production of grazing animals; (4) How to handle areas of seasonably palatable forage on a year-long basis; (5) Effects of different methods of handling on the nutrition of range animals; (6) Effect of elapsed time, including weathering, on nutritional values of range forage plants, and (7) Nutritional values of the principal range forage species by actual feeding tests."

It is evident from the several conferences held to date that the desired progress on this important topic cannot be made satisfactorily until the necessary assistance is made available to (1) compile available information as an aid in the formulation of experimental work for distribution to investigators interested and in a position to give consideration to studies of relative values of pasture, forage, and other crops; and (2) the development of a carefully conceived investigational procedure for consideration by agronomists and animal specialists interested in pasture research. Funds are being sought for this purpose.

John Abbott
B. A. Brown
P. V. Cardon
D. R. Dodd
C. R. Enlow
R. D. Lewis
O. McConkey
George Stewart
Paul Tabor
O. S. Aamodt, *Chairman*

RESOLUTIONS

IT BECOMES the duty of the Committee on Resolutions to announce the deaths of the following members of the American Society of Agronomy during the past year: Dr. J. G. Lipman of New Jersey; Dr. C. F. Shaw of California; Dr. F. W. Tinney of the Bureau of Plant Industry located at Madison, Wisconsin; Dr. A. A. Bryan of the Bureau of Plant Industry located at Ames, Iowa; Professor J. G. Hutton of South Dakota; and Professor F. T. Musbach of Wisconsin.

On behalf of the American Society of Agronomy the Committee makes this announcement with regret and a feeling of real loss. Detailed accounts of these men are attached to this report and will be published in the Journal. Shall we stand in a moment of silence in honor of these agronomists.

M. F. Miller
R. I. Throckmorton
O. S. Aamodt
J. D. Luckett, *ex-officio*
F. D. Keim, *Chairman*

ARTHUR ALFRED BRYAN

ARTHUR ALFRED BRYAN, Agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, died at his home, 712 Ridgewood Avenue, Ames, Iowa, on the morning of February 22, 1939. He had been in poor health for two or three years and his illness had confined him to his home for several weeks.

Doctor Bryan was born at Princeton, Missouri, on December 2, 1890. He entered the College of Agriculture of the University of Missouri in 1912 and graduated with the degree of B.S. in Agriculture in 1915. He was granted the Master's degree by the Iowa State College in 1925 and the Ph.D. degree by the same institution in 1931. From February 1916 to December 1917 he was Scientific Assistant in the Office of Corn Investigations of the Bureau of Plant Industry. In December 1917 he was transferred to the Office of Western Irrigation Agricul-

ture and was Acting Superintendent of the San Antonio Experiment Station, San Antonio, Texas, until February 1920, when he resigned his position and engaged in farming in southwestern Texas. In July 1922 he was appointed Junior Agronomist in the Office of Cereal Investigations and assigned to the Iowa Agricultural Experiment Station in charge of the agronomic phases of the cooperative Iowa Corn Yield Test carried on by the Iowa Corn and Small Grain Growers' Association, the Farm Crops Section of the Iowa Agricultural Experiment Station, and the Office of Cereal Investigations. He remained in this work until January 1934 when he was placed in charge of the cooperative Iowa Corn Improvement Program. From that time until his death his efforts were concentrated on the breeding phases of corn improvement.

In the passing of Doctor Bryan we who were closely associated with him have lost a friend whose integrity, sincerity, and kindliness were unfailing. We have not known a man who set higher moral standards for himself and attained them in so quiet and unassuming a manner. He gave unsparingly of himself to all those associated with him as well as to religious and civic organizations.

Doctor Bryan was an extremely diligent and painstaking worker. The high scientific esteem in which the Iowa Corn Yield Test is held is largely the result of his efforts. Through his interest in statistical methods and improved plot technics he has maintained a standard of perfection in the Yield Test that has made it an outstanding example for experiments of this kind.

Doctor Bryan is survived by his widow, the former Miss Jessie Miller of Newton, Missouri, and by his daughter Phyllis, a junior in Home Economics, at Iowa State College. He also leaves two brothers, Reece Bryan, of Princeton, Missouri, and Roy Bryan, of Mercer, Missouri, and a sister, Mrs. Ike Hoover, of Princeton, Missouri.—MERLE T. JENKINS.

JOSEPH GLADDEN HUTTON

THE American Society of Agronomy lost a valuable member in the death of Professor Joseph Gladden Hutton, in Brookings, South Dakota, September 23, 1939.

Mr. Hutton was born near Montecelo, Indiana, November 3, 1873. He was the son of William H. and Mary J. (Gladden) Hutton. He was reared on a farm and attended a one-room district school. He later attended the Indiana State Normal University at Terre Haute, from which institution he graduated. As a student there he came under the tutilage of Dr. Dryer. He was also assistant in biology, 1898–1900. He was principal of high school and later superintendent of schools, Beardstown, Illinois, 1901–08; received his B.S. degree from the University of Chicago, 1908; and his M.S. from the University of Illinois, 1910. He served as assistant in geology, University of Illinois, 1908–11. June 15, 1904 he was married to Emilie (Feddersen) Hutton; children, Helma Louise (Mrs. H. L. Keil), Mary Erne-Jean (Mrs. Moras Schubert), and Joseph Gladden Jr.

Professor Hutton came to South Dakota State College and Experiment Station in June, 1911, and served this institution continuously as Associate Agronomist in charge of Soils Instruction and Research until the time of his death. He was granted leave from March 5, 1935, to October 1, 1936, to cooperate with the U. S. Soil Conservation Service.

Whatever Mr. Hutton did throughout his career was accurately and thoroughly carried out. The following paragraph received from the Registrar of his Alma Mater in reply to an inquiry for the usual information about his undergraduate

career seems characteristic: ". . . admitted to the University of Chicago on July 3, 1899 . . . His major field was botany. He maintained a scholastic average slightly below A which was unusually excellent. He received honorable mention for excellence in his senior college work and also received honors in botany. Mr. Hutton was elected to Phi Beta Kappa."

He matriculated as a graduate student in the University of Illinois, 1908, and received his degree of M.S. (Geology) in 1910. He had studied Geology with Professor T. E. Savage and Professor S. W. Cushing. In the latter part of his sojourn as a graduate student in Illinois, he studied soils with the late C. G. Hopkins. It is pertinent to say that the academic training which had been secured by Mr. Hutton previous to his study of soils consisting of thorough disciplines in biology and later geology, made it possible for him to become a competent soil scientist. If it is possible to speak relatively of such a matter, he would surely be regarded by his colleagues as one of the most competent men in the country—or in the world.

It was his definite proposition when he came to South Dakota in 1911 to contribute to knowledge in soils with especial reference to correlation between geologic formation and soil type. It was his belief that such correlation is not only fundamental, but that it had not been too clearly emphasized in previous years. Always appreciative of the work of others, his belief in the matter just indicated and his previous training gave direction to his later teaching and investigational work. He learned the relation between soils and farm management from C. G. Hopkins, and what he learned he never forgot. The following statement relative to Mr. Hutton's connection with the American Society of Agronomy was contributed in the following reply from Dean M. F. Miller:

"I find that his large contribution was in connection with the Soil Survey Association. He was Vice-president of this Association in 1928–29 and President in 1929–30. He served on a number of committees, the most important of which were as follows:

"Chairman of the Committee on Soil Color Standards, 1920–1932. He did much original work in connection with his assignment, making a real contribution to the methods of evaluating soil colors to be used in connection with soil classification. He presented reports at the annual meetings regularly during this 12-year period.

"Chairman of the Committee on Land Use, 1932–33. This was in the early days of the interest in land-use activities, and a committee was set up in the Soil Survey Association for this purpose. However, this was discontinued in 1933 under this title and was set up as a committee on Soil Conservation.

"Chairman of the Committee on Soil Conservation, 1933–36. He presented regular reports in connection with this important subject during these eventful years. However, in 1936, the Soil Survey Association was merged with the Soils Section of the American Society of Agronomy, and these various committees were discontinued.

"Professor Hutton was widely known among soil scientists for his work in connection with soil classification and soil survey. He was a regular attendant at the annual meetings and each year appeared on the program. He had a host of friends."

The foregoing activities in connection with scientific soils organizations—state, national, and international—may be regarded as important, and withall as as effective as any other work he did. He labored diligently at it, much of the time intensely. During his period of work in South Dakota the state legislature financed

a state soil survey through the years 1917–27, during which time Mr. Hutton was in direct charge of soil survey and soil research for the state. Nine counties were surveyed in cooperation with the then U. S. Bureau of Soils. The late Dr. C. F. Marbut was director of the Soil Survey and W. I. Watkins, cooperator here in the field. The late Thomas D. Rice was inspector. More recently a soil area map (unpublished) was composed as a result of a survey of South Dakota by Joseph Gladden Hutton and W. I. Watkins. The foregoing soil surveys directed or participated in by Mr. Hutton have contributed mainly to knowledge of soil types and areas in South Dakota. Recently Mr. Hutton published "Thirty Years of Soil Fertility in South Dakota" (South Dakota Agr. Exp. Sta. Bul. 325). This bulletin is intended to be a summary of crop yields resulting from differential treatments under conditions of environment in this area. People who know about the details of carrying through soil and crop experiments over long periods with or without plenty of advice from democracy will be able to appreciate such a contribution. Mr. Hutton was author or co-author of a number of bulletins and circulars, likewise of various papers in scientific journals.

He was a member of American Society for Advancement of Science, the American Society of Agronomy, American Genetic Association, National Geographic Society, State academies of South Dakota, Indiana, and Illinois, International Society of Soil Science, Alpha Zeta, and Sigma Chi. He served during the World War with the rank of Second Lieutenant.—A. N. HUME.

JACOB GOODALE LIPMAN

WITH the passing of Doctor Lipman, American agriculture has lost a brilliant investigator and an outstanding contributor to our knowledge of the soil and its relation to plant growth and agricultural practice.

A graduate of Rutgers College of the Class of 1898, a member of the staff of the New Jersey Agricultural Experiment Station since 1899, with only a brief interruption for graduate work, Director of the Experiment Station since 1911 and Dean of the College since 1914, Dr. Lipman has played a most important role in the building of these institutions from a small foundation to one occupying a leading place among the teaching and research institutions in this country. His keen scientific mind, his practical approach to the many difficult problems that he had to face, his outstanding administrative ability, and especially his profound humanitarianism in his relation to his colleagues and his subordinates, were well recognized. Following closely in the footsteps of his two distinguished predecessors, Dr. George H. Cook and Dr. E. B. Voorhees, Dr. Lipman continued their pioneer work in the field of agricultural science and signally succeeded in bringing together science and practice for the common good.

In his own selected field of work, namely in soil science, Doctor Lipman has occupied an outstanding place. His own contributions to our knowledge of the problems of nitrogen-fixation, decomposition of organic matter, and denitrification have attracted world-wide attention. Doctor Lipman's writings, including his book "Bacteria in Relation to Country Life"; the journal of SOIL SCIENCE, which he established and edited for a period of 24 years; his editorship of various monographs in agricultural science; his contributions to numerous farm journals and agricultural encyclopedias—all stand out among his great achievements.

Outstanding among the contributions of Doctor Lipman was his leadership in the scientific societies of this country and of the world at large. As former President of the Association of Land Grant Colleges and Universities, as President of

the American Society of Agronomy of which he was a charter member, and as first President of the International Society of Soil Science, he has helped to crystallize the progress made in agricultural science. This was acknowledged by numerous national and international societies, as evidenced by the many honors showered upon him by governments, universities and scientific societies, by medals and memberships of editorial boards of foreign and domestic journals, etc. He served as American delegate to the International Institute of Agriculture at Rome in 1922, 1924, and 1926, to the International Conference of Soil Science in Prague in 1922 and in Rome in 1924, as President of the First International Congress of Soil Science at Washington in 1927 and as chairman of the American delegation to the Third International Congress of Soil Science in 1935 at Oxford, England. In 1929 he was designated to serve as one of the representatives of the state experiment stations on a national committee on soil erosion to formulate plans for a national approach to this important problem. He served on numerous committees of a national or of a state nature.

The recognition of the importance of microbiological processes in soil fertility and in plant nutrition was well expressed by Dr. Lipman in one of his chapters on the "Microbiology of the Soil" published, in 1911, in Marshall's Microbiology. "Soil-formation is not entirely a mechanical or chemical process. Even before the layer of weathered rock acquires any appreciable depth, microscopical and macroscopical forms of life gain a foothold on the uneven surface. With the aid of sunlight they build organic compounds and make use of the combined or elementary nitrogen of the atmosphere. Their life activities result in the production of carbon dioxide and of varying organic and inorganic acids which in their turn react with the constituents of the rock particles. In this manner the biological activities become of utmost moment in the transformation and migration of mineral substances in nature. Soil science must build a foundation large enough and strong enough to support the study of plant food resources and their mobilization, of the inter-relations of soil and plants and of soil characteristics and peculiarities as reflected in the make-up of plants, animals and man. As students of soils and soil resources we must think not only of plant-food but of its mobilization. We must consider the soil solution not alone in its local relations, but as a part of a great mass of fresh water moving to the sea. We must consider the cubic miles of sediment deposited at the outlets of great rivers as a toll upon the land and as a tax on those who till it. We must include in our reckoning the circulation of carbon, hydrogen, nitrogen and sulfur as affected by combustion, decay and fermentation. We must think, finally, of ancient plant and animals, as well as of those now living, as possessors of something that in the workshop of creation must be used over and over again. We are the technical advisers to the nations who are trustees of precious raw materials. These must be used wisely and conserved effectively in order that human kind may travel with the least pain and sorrow on its road of destiny."

The contributions of Doctor Lipman to soil science were well expressed by Sir John Russell, in an article published in the fortieth volume of SOIL SCIENCE dedicated to its editor: "He began his work at a critical period in the history of agriculture. The new science of bacteriology, just being applied to agriculture, had revealed a new and hitherto completely unexpected world of life-living organisms so small and yet so numerous that the mind utterly failed to grasp the figures expressing either their size or their number. In the agricultural laboratories the achievements of Winogradsky, Beijerinck, Warington, and others had shown a wonderful picture of soil life, rousing the imagination and stimulating the scien-

tific interest of many of the younger workers of the day. They had used culture methods, in the main the elective methods, excluding all organisms but the one under investigation and they had achieved marvelous results. Doctor Lipman began also by using these methods to study a question which was then causing considerable commotion in agricultural circles, the loss of nitrogen from farmyard manure. This had always been regarded by practical men as the ideal fertilizer, and the battle of the giants of those days raged about the question; farmyard manure versus artificials. His discovery that Azotobacter by itself can fix nitrogen is of historic importance, but equally valuable was his gradual recognition of the importance of the compositions of organic matter—its carbon-nitrogen ratio—on its decomposition in the soil."

The loss of Doctor Lipman's leadership, his scientific acumen, and his humanitarian qualities are profoundly felt, not only by those who were in close daily contact with him, but also by his innumerable friends and his former associates and students scattered throughout this and many foreign countries. To few men is it given to exert such a profound influence on so many fields of scientific endeavor, and to become an inspiration and help to so many of his fellow men.—SELMAN A. WAKSMAN.

FREDERICK LUDWIG MUSBACH

FREDERICK LUDWIG MUSBACH, Professor of Soils in the Wisconsin College of Agriculture, was killed in an automobile accident September 14, 1939. He was born on a Wisconsin farm March 10, 1877. After completing his course in the Milwaukee Normal School he taught a few years before coming to the University and was graduated from the College of Agriculture in 1909. He was at once appointed assistant in the college. His first assignment was that of making a reconnaissance survey of two large areas in northwestern Wisconsin, a job he completed in a very credible manner.

In 1912 Professor Musbach was placed in charge of the research work on soil management on the northern Wisconsin substations in which he was engaged until his death. In 1937 the people of that region celebrated the completion of 25 years which he had devoted to the study of their soil problems and erected a plaque expressing their appreciation of his labors in their behalf.

Professor Musbach attended the second meeting of the American Society of Agronomy at Omaha and was a member and regular attendant on essentially all meetings thereafter. His more important contributions have been based on studies of the silt loam soils derived from old glacial drifts in a region of crystalline rocks in the north central and most intensive dairy region of the state. These studies included work on methods of maintaining organic matter, of their fertilizer needs, and of the physical and chemical conditions in relation to the growth of legumes, especially of alfalfa. For a number of years he has given special attention to the soil and fertilizer problems of the two most important special crops of Wisconsin, namely canning peas and potatoes.

His papers in the JOURNAL deal with the relation of weather as a factor in crop production and on the effect of fertilizers on the quality and chemical composition of canning peas. His last paper, in cooperation with Professor J. C. Walker, is a study of the relation of root rot infestation of peas to fertilizer application and will appear soon in the JOURNAL OF AGRICULTURAL RESEARCH.

In addition to papers on research projects Professor Musbach wrote a number of bulletins of an extension character on various soil problems of the region.

Professor Musbach was a man of exceptionally fine personality, of great physical and intellectual energy, and was a recognized leader in the educational and civic groups of the region of his life's work. Announcement has just been made that in his will he has provided that half of his estate will be given to the College of Agriculture for the establishment of fellowships providing for further study of the problems of soil management. His wife, an invalid for many years, died in January of this year and their only child, William F., is now engaged in work with the Department of Agricultural Economics following completion of his graduate work at the University of Wisconsin.—A. R. WHITSON.

CHARLES FREDRICK SHAW

CHARLES FREDRICK SHAW, Professor of Soil Technology at the University of California, and Soil Technologist in the Agricultural Experiment Station, passed away in Berkeley, California, on September 12 after a brief illness. Born in West Henrietta, New York, May 2, 1881, after a brief period of preparatory schooling he entered Cornell University from which he was graduated in 1906. Shortly after graduation he was appointed Scientific Assistant in the Division of Soil Survey, Bureau of Soils of the U. S. Dept. of Agriculture. After a period of service in soil survey work in Louisiana and Texas he accepted an appointment as Instructor in Agronomy at the State College of Pennsylvania in 1907 where he became Assistant Professor of Agronomy in 1909. During his period of service at Pennsylvania State College he participated in soil surveys in cooperation with the Bureau of Soils in various areas in that state.

In 1913, under Dean and Director Thomas F. Hunt, who gathered about him a group of very able men, Professor Shaw was called to the University of California to a position which he occupied and faithfully filled, except for brief periods of leave, until his death. In addition to a heavy burden of teaching, he found time for activity in research and publication of numerous technical papers dealing with soil surveying and soil classification, and under his able direction a program of soil surveys in California in cooperation with the Bureau of Soils, later Bureau of Chemistry and Soils and Bureau of Plant Industry, was built up. During this period a total of more than 60 detailed and reconnaissance soil surveys were completed, in addition to which he conducted a number of independent soil surveys and studies in the state for the California Department of Public Works and other official and local organizations.

He was widely traveled, accompanied by Mrs. Helen Hosterman Shaw whom he married in 1909. He visited and studied soil and agricultural conditions in Australia, New Zealand, Hawaii, and many other regions and countries. In 1930 he was Visiting Professor at the University of Nanking where he conducted extensive field studies in China and laid the basis for systematic soil surveys later undertaken. Several summer periods were spent in Mexico in an advisory capacity to the National Commissioner of Irrigation in teaching and training a corps of men in soil surveying. He served at various times as a member of various advisory committees and in field investigations for the U. S. Reclamation Service and other federal and state organizations.

He was a member of the International Society of Soil Science and official delegate of the University of California to International Soil Congress sessions held in Washington, Russia, and England in the proceedings of which he took active part, and had been asked to succeed the late Dr. C. F. Marbut as Chairman of Commission V, Subcommission for North America. He was a Fellow of the

American Society of Agronomy, of the American Geographical Society, and of the American Association for the Advancement of Science, and a member of the Soil Science Society of America and a past President of the American Soil Survey Association which preceded it. He was also a member of the American Society of Agricultural Engineers, Western Society of Soil Science, California Academy of Sciences, and of other scientific, fraternal, and social organizations, including Alpha Zeta and Sigma Xi. Funeral services attended by a large circle of associates and friends were conducted with Masonic rites.

In his office as teacher his advice and counsel was constantly sought and freely given, for it was his province not only to teach but to inspire. Good teacher—good scientist—good citizen—good friend.—MACY H. LAPHAM.

FRED WILLIAM TINNEY

FRED WILLIAM TINNEY was born at Saco, Montana, October 30, 1907. After graduation from the local high school, he entered the State Teachers' College, Oshkosh, Wisconsin, where he received the degree of B.Ed. in 1929. He spent two years at the University of Oklahoma as assistant in botany, taking an M.S. degree in 1931. He then came to the University of Wisconsin as research assistant, which position he held until his appointment, in February, 1936, as assistant agronomist in the Bureau of Plant Industry, U. S. Dept. of Agriculture. The degree of Ph.D. was received in 1933.

His research included a thorough-going study of heteropycnosis in two species of *Sphaerocarpos*. After this came an investigation of the cytology of an ornamental grass, *Agrostis nebulosa*. This led naturally to the study of the genetics and cytology of pasture grasses. After Dr. Tinney's appointment in the Bureau of Plant Industry, work in this field was carried on at Madison in cooperation with the Department of Agronomy of the University of Wisconsin. A paper embodying his extensive studies of blue grass (*Poa pratensis*) is in press. This grass has been the source of much confusion because of the multitude of races included within the species, and of the variety of chromosomal conditions which these races manifest. Tinney's observations of the peculiar methods of embryo-sac and embryo-development characterizing the species go far toward explaining the peculiar genetic behavior of its varied forms. It promises, too, to supply a basis for the selection and breeding of improved strains of this and other grasses—a relatively new field of endeavor in America.

Deeply devoted to fundamental research in accordance with his training and inclinations, Doctor Tinney in his later work developed a keen insight into the applied aspects of his studies. Quiet and unassuming, he was highly respected by his fellow workers and many friends, who recognized in him the qualities of substantial leadership among the younger group of American scientists.

He married Madeline Morrissey on June 12, 1939. Both Doctor and Mrs. Tinney attended the International Congress of Genetics at Edinburgh and were passengers on the ill-fated *Athenia* sunk off the coast of Scotland, September 3, 1939. They were among those listed as missing after the disaster.—C. E. ALLEN, R. A. BRINK, and L. F. GRABER of the University of Wisconsin, and O. S. AAMODT, of the Bureau of Plant Industry.

NOMINATING COMMITTEE

THE Nominating Committee consisting of R. J. Garber, *chairman*, and F. D. Keim, W. A. Albrecht, H. C. Rather, and A. M. O'Neal, made the following nominations: Dr. Richard Bradfield of Cornell Universiry as representative on the Union of Biological Sciences; Dr. R. M. Salter of the Ohio Agricultural Experiment Station and Dr. S. T. Dexter of Michigan State College as representatives of the Society on the Council of the American Association for the Advancement of Science; and for Vice-President of the American Society of Agronomy, Dr. L. E. Kirk of Ottawa, Canada.

Upon motion the Secretary was instructed to cast one vote for these nominees and they were declared unanimously elected.

Respectfully submitted,
G. G. POHLMAN, *Secretary*.

AGRONOMIC AFFAIRS

OFFICERS OF THE AMERICAN SOCIETY OF AGRONOMY FOR 1940

President, F. J. ALWAY, University of Minnesota.
Vice-President, L. E. KIRK, Dominion Agr. Exp. Station, Ottawa, Canada.
Chairman, Crops Section, S. C. Salmon, U. S. Dept. of Agriculture.
Chairman, Soils Section, W. H. PIERRE, Iowa State College.
Editor, J. D. LUCKETT, New York State Agr. Exp. Station.
Secretary-Treasurer, G. G. POHLMAN, West Virginia Agr. Exp. Station.
Members of the Executive Committee, R. J. GARBER, U. S. Dept. of Agriculture, and EMIL TRUOG, University of Wisconsin.

OFFICERS OF THE CROPS SECTION FOR 1940

A NOMINATING Committee appointed by Professor F. D. Keim, *Chairman* of the Crops Section, at the business meeting of the Section held in New Orleans November 22 was composed of R. D. Lewis, *Chairman*, and R. G. Wiggans and M. T. Jenkins. The committee presented the following slate of officers for the Section for 1940 which was unanimously approved: For *Chairman*, S. C. Salmon of the U. S. Dept. of Agriculture, and as members of the Executive Committee of the Section, P. C. Mangelsdorf of the Texas Agr. Exp. Station and C. J. Willard of Ohio State University.

OFFICERS OF THE SOIL SCIENCE SOCIETY OF AMERICA FOR 1940

President, W. H. PIERRE, Iowa State College.
Past President, WM. A. ALBRECHT, University of Missouri.
Secretary, C. E. KELLOGG, U. S. Dept. of Agriculture.
Treasurer, G. G. POHLMAN, West Virginia Agr. Exp. Station.
Editor, J. D. LUCKETT, New York State Agr. Exp. Station.

Section I

Chairman, J. F. LUTZ, North Carolina State College.
Past Chairman, G. B. BODMAN, University of California.
Secretary, WILLARD GARDNER, Utah State Agr. College.

Section II

Chairman, M. S. ANDERSON, U. S. Dept. of Agriculture.
Past Chairman, J. W. TIDMORE, Alabama Polytechnic Institute.
Secretary, C. E. MARSHALL, University of Missouri.

Section III

Chairman, A. W. HOFER, New York State Agr. Exp. Station.
Past Chairman, N. R. SMITH, U. S. Dept. of Agriculture.
Secretary, O. H. SEARS, University of Illinois.

Section IV

Chairman, W. H. METZGER, Kansas State College.
Past Chairman, J. J. SKINNER, U. S. Dept. of Agriculture.
Secretary, J. A. NAFTEL, Alabama Polytechnic Institute.

Section V

Chairman, T. M. BUSHNELL, Indiana Agr. Exp. Station.
Past Chairman, S. S. OBENSHAIN, Virginia Agr. Exp. Station.
Secretary, H. H. KRUSEKOPF, University of Missouri.

Section VI

Chairman, H. E. MIDDLETON, U. S. Dept. of Agriculture.
Past Chairman, W. L. POWERS, Oregon State College.
Secretary, W. W. WEIR, University of California.

MEMORIAL SERVICE FOR DOCTOR LIPMAN

A memorial service for the late Dr. J. G. Lipman was held at Temple Emanu-El, Fifth Avenue and 65th Street, New York City, on Sunday afternoon, November 26, 1939, under the auspices of a number of learned societies and organizations, including the American Society of Agronomy. Among the speakers at the service were Dr. Henry G. Knight of the U. S. Dept. of Agriculture, Dr. Gabriel Davidson of the Jewish Agricultural Society, Professor O. S. Morgan of Columbia University, Dr. Carl B. Woodward of Rutgers University, Dr. Harold B. Allen of the National Farm School, and Dr. Arthur D. Goldhaft of the Baron de Hirsch Agricultural School.

JOHN JACOB PIEPER

DR. John Jacob Pieper died November 26 at Pana, Illinois, as a result of a heart attack while on his way home from the New Orleans meeting of the American Society of Agronomy. Doctor Pieper was Professor of Crop Production in the College of Agriculture, and Chief in Crop Production in the Agricultural Experiment Station, University of Illinois, with which he has been connected for 22 years.

Doctor Pieper graduated from the University of Illinois in 1916; received the M.S. degree from the same institution in 1917; and ob-

tained the Ph.D degree at the University of Wisconsin in 1927. He was a member of the American Society of Agronomy, and the Sigma Xi, Alpha Zeta, Phi Sigma, Gamma Sigma Delta, and Theta Chi fraternities.

In addition to his striking success as a teacher, he made noteworthy contributions in the field of research. During the later years he gave special attention to the subjects of pasture improvement and weed control. The long list of bulletins, circulars, and journal articles, of which he is author or co-author, testify to his productiveness in the field of research.

NEWS ITEMS

ON SEPTEMBER 1, D. D. Mason, Assistant Agronomist, Virginia Agricultural Experiment Station, resigned from his duties as Soil Surveyor to accept a fellowship in the Agronomy Department at Ohio State University, where he hopes to take the Ph.D. degree in Soil Fertility. Mr. Mason received his M.S. degree in Agronomy from Virginia Polytechnic Institute in June 1938. Mr. Ashton Sinclair, a 1938 graduate of V. P. I., was added to the Experiment Station staff to fill the vacancy caused by Mr. Mason's resignation.

DR. WERNER HUSMANN, a graduate of the University of Berlin, and formerly connected with the German Nitrogen Syndicate, was employed as Assistant Professor of Agronomy at Virginia Polytechnic Institute, effective October 5.

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